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The Viking Formation (Lower Cretaceous) of southeastern Saskatchewan.

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THE VIKING FORMATION (LOWER CRETACEOUS) OF SOUTHEASTERN SASKATCHEWAN

by

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ABSTRACT

The Viking Formation is a dominantly regressive sequence of sandstones, laid down in a shallow, marine epicontinental basin. The Viking sequence of southeastern Saskatchewan was deposited on the eastern shelf of this basin. It is disconformable with the underlying, transgressive Joli Fou Shale Formation and conformable with the overlying, transgressive Big River Shale Formation.

The Viking succession is a multistorey sandstone body. The sandstones are fine- to medium-grained with a low textural and compositional variability. There is a high percentage of intercalated siltstones and mudstones present within the Formation. Interlaminated sand-mud intervals; low-angle, bi-directional cross-bedding; wavy bedding and starved ripples indicate deposition from tidal currents. Small-scale graded units, representing storm-generated layers, are also present. The Formation is extensively bioturbated and a high percentage of carbonaceous, organic material is present.

In the study area, the Formation can be divided into lithologically similar eastern and western parts. In the western part the sandstone forms a broad sheet, averaging between 20 and 40 m in thickness. Within this sheet, thick and thin anomalies are elongated in a northeast-southwest direction. It appears to have an imbricate internal structure with the younger sands overlapping the older sands in a westward direction. This appears to be a tidally deposited, offshore marine, sheet sandstone, laid down parallel to the associated shoreline. Immediately to the east of this, the sandstone is poorly developed, forming thin, discontinuous bodies averaging between 2 and

20 m in thickness, with a lobate northeast-southwest distribution. These are tidally deposited, marine bars and sand ridges.

Viking sandstone distribution in southeastern Saskatchewan is seen to be broadly similar to that of the Newcastle Formation in northwest North Dakota, indicating similar depositional controls across this area.

A large, solution-formed depression is present at the intersection of the Hummingbird Trough and a prominent northeast-southwest trending, structural linear. This was formed in post-Lower Colorado time. A solution depression is also present in the region overlying the Nelson River High. This was formed during the deposition of the Joli Fou Shales and results in local isopachous thickening of that Formation. Antecedent drape folding of the Viking Formation above topographic highs on the Mississippian erosion surface is also demonstrated.

The Viking lithology and structure in this area is compared favourably with that of hydrocarbon-producing areas in western Saskatchewan. There are many highly promising stratigraphic and structural trends formed in this area by updip pinchout and the development of secondary structural features within the Formation.

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INTRODUCTION

Location

The study area (Fig. 1) is in southern Saskatchewan, extending from the Manitoba border as far west as, and including Range 17, west of the Second Meridian, and from the United States border as far north as, and including Township 20.

The Problem

The Lower Colorado Subgroup was laid down in an epeiric, epicontinental sea within the Williston Basin of Saskatchewan. It was marked by two main transgressions and an intervening regression ; the latter gave rise to the extensive Viking Sandstone. This was laid down on the eastern and western shelves of the Colorado Basin.

There is extensive hydrocarbon production in Alberta and Saskatchewan from the western shelf sediments. There has been no corresponding production from equivalent sediments of the eastern shelf in spite of the hydrocarbon showings in Saskatchewan, Manitoba and North Dakota. As a consequence of this, detailed stratigraphic knowledge of the eastern shelf has lagged considerably behind that of the western shelf.

Previous work

The term Viking Formation was first used by Slipper (1917) for an oil-producing sandstone in east-central Alberta. Previous work on the Viking Formation of southeastern Saskatchewan has been carried out by Price (1963) in a study of the Lower Cretaceous in this area. He

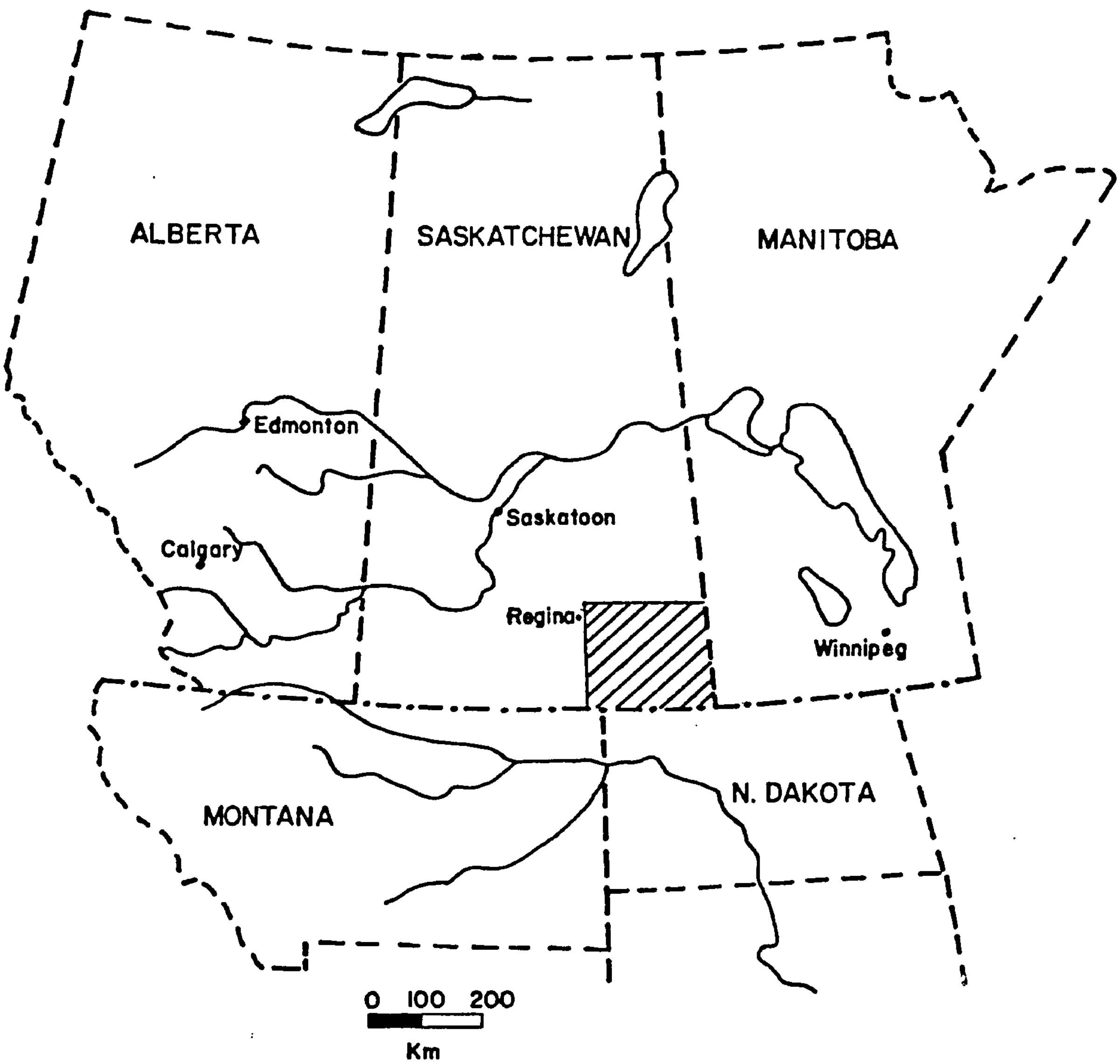


Figure 1 - Location of Study Area.

described the Viking Formation as a lithic sandstone, thinning northeastwards from 46 m at the Third Meridian near the forty ninth Parallel to 27 m near the Manitoba border at Township 35. This trend is interrupted by local thickening. He described the Formation as forming a broad, diagonal band across the area with tongues or lobes extending towards the northeast. He stated that there is no single explanation as to its origin, but that it represents a temporary regression in an overall, deep-water, transgressive sequence, consisting of underlying and overlying, non-calcareous, marine shales.

A study of the Viking Formation in southwestern Saskatchewan was carried out by Jones (1961). He described it as forming generally lenticular sandstones, siltstones and shales. He determined that the structure of the Formation had been affected by drape folding of the Lower Colorado sediments over a pre-Cretaceous erosion surface. He regarded the Formation as neritic or littoral in origin, with possible beach deposition.

Staubo (1970) carried out a general study of the Viking Formation in southeastern Saskatchewan. He described it as forming narrow, elongate sand-bodies deposited by tidal currents in a shallow, marine sea. He concluded that the sediments were derived from a source, situated to the north of the study area.

Simpson (1975) dealt with the Viking Formation in his study of the Colorado Group in Saskatchewan. He regarded the Viking Formation as a regressive sequence, represented in the west by nearshore sands and the analogues of modern tidal sand ridges, passing basinward into mudstones to form a graded shelf. He regarded the Viking in the east as representing tidal channels in a nearshore to proximal shelf depositional environment. He stressed the importance of storm-generated currents in the formation of graded beds within the Formation. He also determined east-west stratigraphic relations within the Bow Island-Viking succession.

Extensive work on the Newcastle Formation, which is the equivalent of the Viking Formation in the North Dakota-Montana region, has been done by Hansen (1955), Wulf (1962), Anderson (1967) and Reishus (1968). These studies have examined in particular the lithological characteristics, depositional systems, and structural and isopachous trends of the Newcastle Formation within this area.

Scope of Study

The purpose of this study is to determine the structural and stratigraphic relationships of the Viking Formation in southeastern Saskatchewan. The mechanisms and the environment of deposition and the diagenetic history of the sandstone are examined. These considerations are related to the hydrocarbon potential of the area.

The investigation employed subsurface data in the form of geophysical well logs and cores. The electric logs of 512 wells were examined. A well density of approximately one well per township was used, with additional wells along lines of section. Slightly less than 20 per cent of the townships within the area contained no suitable well logs.

The information from these well logs was used to prepare isopachous and structure contour maps of the Lower Colorado Subgroup and the units contained within it. Log correlations were made to provide both generalised and detailed sections of the Lower Colorado and particularly the Viking depositional systems. This information was also used to extend into the study area various trends established by authors using similar techniques in North Dakota.

Owing to the fact that the prime interest in hydrocarbon exploration in this area has been aimed at targets below the Cretaceous, relatively few cores have been taken from the Viking Formation. All available cores from the study area, which included rocks of this Formation, were examined. This came to a total of ten wells. Nowhere in the study area was the complete Viking succession cored. Of the ten wells, seven were wire-line cores. Two additional cores of the Formations, immediately overlying and underlying the Viking Formation, were examined. Descriptions of these cores are presented in Appendix I. The complete Viking succession was examined in a core, taken from the Imperial Esk 7-14-33-20 well (LSD 7-14-33-20 W2), which is north of the study area. A description of this core is presented in Appendix I(a).

Seven thin sections were prepared from samples obtained from cores within the study area. Descriptions of these thin sections are presented in Appendix II. These were supplemented by seven thin sections, prepared from cores taken from outside the study area, but from the same broad depositional system. The location of these thin sections is shown in Appendix II(a). These were used in a broad petrographic study of the Formation.

REGIONAL SETTING

Generalised Depositional History

The main source of information used for this generalised depositional history of the area is that of Christopher et al. (1971). The Viking Formation was laid down in a shallow, epicontinental marine basin, centered in North Dakota and known as the Williston Basin (Fig. 2). This basin was formed in mid Jurassic times as a result of the Nevadan orogeny. An ancestral Williston Basin had existed in this area during the Palaeozoic. This was terminated in Late Mississippian times by a major uplift which created hiatus that extends to the Early Jurassic in southern Saskatchewan.

The Jurassic and basal Cretaceous sediments of this area were laid down on a karst topography, dissected across the southerly tilted Upper Palaeozoic carbonate-evaporite succession. The Jurassic consists of a transgressive sequence of terrestrial red beds, marine carbonates, shales and sandstones. The initiation of the Nevadan upheaval to the west ended the Jurassic marine transgression by uplifting the area and creating the structural outlines of the Williston Basin.

Slow subsidence of the Williston Basin during the Cretaceous gave rise to a dominantly marine, transgressive sequence. The basal Cretaceous consists of fluvial and lacustrine deposits, giving way to a siliciclastic, marine sequence. This was succeeded by a dominantly transgressive, argillaceous marine sequence, which was repeatedly interrupted by minor, short-lived regressions giving rise to thin sandy units.

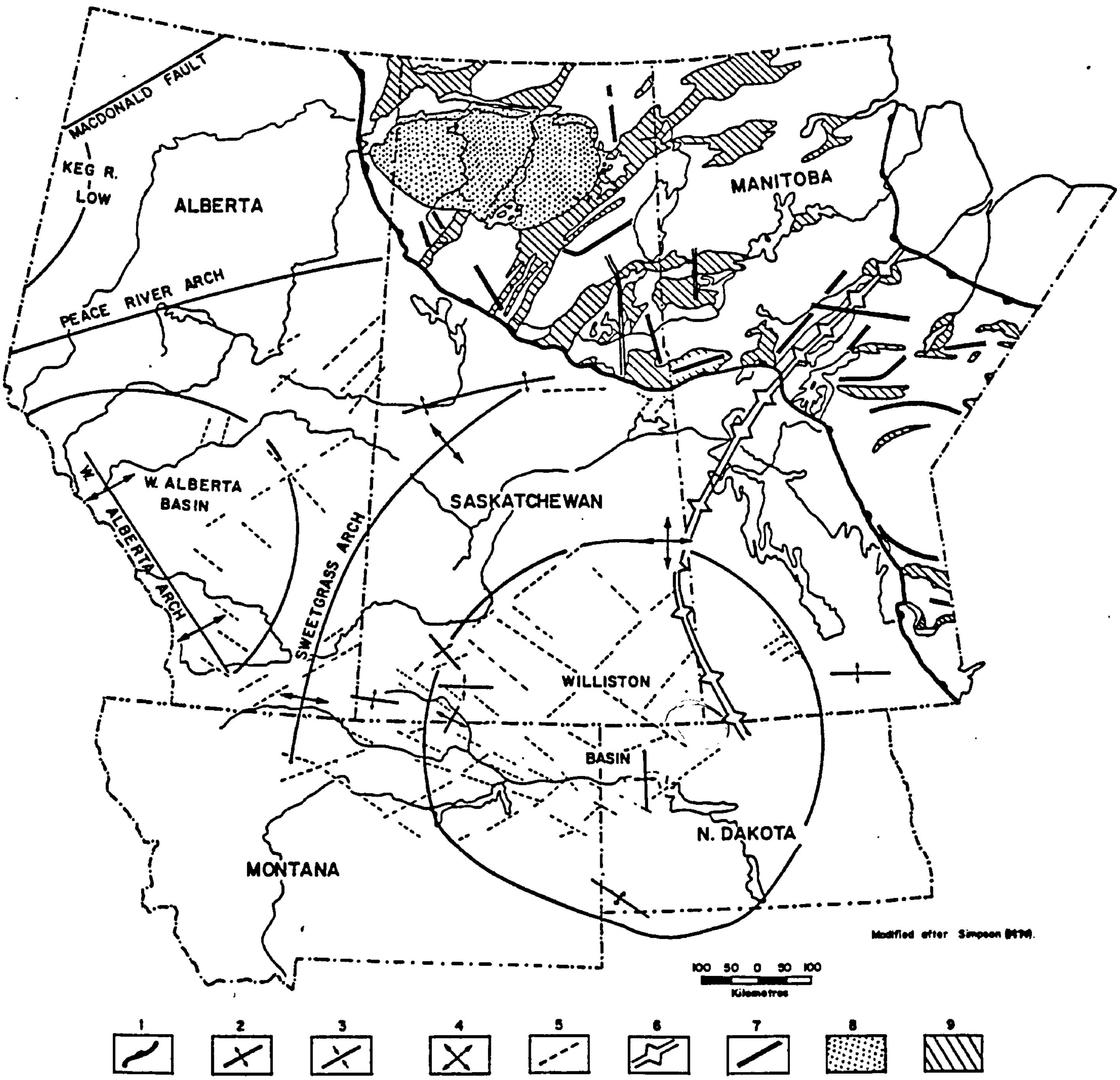


Figure 2 - STRUCTURAL ELEMENTS IN THE NORTH WILLISTON BASIN REGION AND ADJACENT AREAS

1. Perimeters of the Precambrian Shield.
2. Arch Form.
3. Trough Form.
4. Domal Feature.
5. Lineament.
6. The Nelson River High; a twin aeromagnetic and gravity anomaly set.
7. Fault zones within the Shield area.
8. The Athabasca Basin.
9. Greenstone Belts.

The Viking Formation consists of sandstones laid down during a regression on broad shelves in a shallow, basin setting. Deposition on the western shelf was controlled by a structural arch called the Sweetgrass Arch (Fig. 2). This played an active part in sedimentation, in that it acted as a baffle to the dispersal of sands from the west Simpson (1979a). Thick clastics were laid down in the Western Alberta Basin as a result of erosion from the rapidly rising Cordilleras. These thin towards the arch so that the remaining sand body is the Viking sequence. This extends across the arch on to the western shelf of the Williston Basin.

On the eastern shelf of the Williston basin the Viking is thinner than in the west. It has an eastern provenance and is derived from erosion of the Precambrian shield. Both eastern and western Viking sandstones are absent in the central portion of the basin where an undifferentiated mudstone-siltstone sequence is present.

Marine deposition in the Williston Basin was terminated in the Upper Cretaceous by gradual, cratonic uplift, giving rise to a Late Cretaceous, continental, clastic sequence.

Outline of Stratigraphy

The Lower Cretaceous stratigraphy of the Williston Basin and surrounding areas is summarised in Table I.

The Viking Formation is Lower Cretaceous in age and forms part of the Lower Colorado Subgroup. The Lower Colorado Subgroup which is mid-Albian to Cenomanian in age, is underlain by the basal Cretaceous Mannville Group, which is Early Neocomanian to Mid-Albian in age. In

	SOUTHEAST ALBERTA		SOUTHWEST SASKATCHEWAN		NORTHEAST MONTANA		NORTH DAKOTA		SOUTHEAST SASKATCHEWAN	WESTERN MANITOBA	
Upper Cretaceous	First White Speckled Shale	Colorado Group (Upper)	First White Speckled Shale	Colorado Group	Niobrara	Colorado Group	Niobrara	Colorado Group	First White Speckled Shale	Vermilion River	Pembina
										Vermilion River	Boyne
	Cardium / M. Hat		Medicine Hat		Carlile		Carlile		Unnamed Shale	Vermilion River	Morden
	Second White Speckled Shale		Second White Speckled Shale		Greenhorn		Greenhorn		Second White Speckled Shale	Favel	Morden
	Fish Scale Zone		Fish Scale Zone		Belle Fourche		Belle Fourche		Big River	Ashville	
Lower Cretaceous	Bow Island: 1st B.I. Sand	Colorado Group (Lower)	Big River		Mowry		Mowry		Big River	Ashville	
	Bow Island: Red Speckled Shale		Viking		Bow I - Newcastle		Newcastle		Viking	Ashville Sand	
	Bow Island: 2 & 3 BI Sand		Joli Fou		Skull Creek		Skull Creek		Joli Fou	Ashville	
	Mannville	Mannville	Pense	Kootenai	First Cat Creek		Fall River	Mannville	Pense	Swan River	
			Cantaur		2nd Cat Creek		Fuson		Cantaur		
			Success		3rd Cat Creek		Lakota		Success		

TABLE I Stratigraphic Correlation Chart for the Northern Williston Basin Region.

southern Saskatchewan the Lowermost Formation of the Lower Colorado is the Joli Fou Formation. In North Dakota and northeast Montana, this is represented by the Skull Creek Shale. In western Manitoba, it is continuous with the lower part of the Ashville Shale.

The Joli Fou Formation is succeeded by the Big River Shales in the south, central and parts of eastern Saskatchewan. In western and eastern Saskatchewan these Formations are separated by the Viking Sandstone. This is continuous to the south with the Newcastle Sandstone in Montana and North Dakota. To the east in southern Manitoba, the Viking is represented by the Ashville sands. The top of the Lower Cretaceous is taken as the base of the Fish-Scale Zone, which is a sand occurring within the Big River Shales. The Big River Formation equivalents in Montana and North Dakota are the Mowry and Belle Fourche Shales.

The bottom of the Upper Colorado Subgroup is taken at the base of the Second White Speckled Shale. The equivalent of this in Montana and North Dakota is the Greenhorn Formation. In western Manitoba, it is represented by the Favel Formation. The Upper Colorado sequence is Turonian to Santonian in age.

The Upper Colorado sediments are succeeded in the area of the Williston Basin by those of the Montana Group, which mark the eventual regression and disappearance of the Cretaceous sea.

STRUCTURE

The Cretaceous succession in Saskatchewan forms a broad, gently dipping shelf, i.e., a homocline with a north to northwest strike and a southerly dip, averaging between 2 m/km and 3.7 m/km, increasing to 9.4 m/km in southeast Saskatchewan and southwest Manitoba (Christopher et al., 1971).

This simple structural form has, however, been profoundly influenced by three major factors. These are :

(1) Basement tectonics. This has led to the formation of major arch and trough forms within the region.

(2) Solution-generated collapse. This has led to the formation of structural lows and elongated trough forms within the region.

(3) The sub-Mesozoic unconformity. This has transmitted in part its topographic character to the Mesozoic structure.

Basement Tectonics

The basement, underlying the sedimentary cover in this region, is believed to be a continuation of the Churchill and Superior Precambrian Provinces, exposed to the north and to the east of this area respectively. These provinces are made up of highly metamorphosed greenstone belts, set in a granitic-gneissose terrain. The structural features of the Churchill Province have a northeast-southwest trend. The greenstone belts are folded about a northeast-southwest axis, and the major fault zones have a northeast-southwest strike with a well developed northwest-southeast conjugate set. The structural features of the Superior Province display an east-west trend.

The basement structural trends deduced to have been active in the Phanerozoic of the north Williston Basin region, is depicted in Figure 2. Among the main features are the northeast plunging Sweetgrass Arch and the east-northeast trending, south plunging, North Battleford Arch, in western Saskatchewan. Smaller features, the Swift Current and Val Marie arches, are developed in southwestern Saskatchewan. Prominent linear features, such as the Meadow Lake Escarpment in west-central Saskatchewan and the Nesson and Cedar Creek anticlines in the North Dakota and Montana regions, are also present.

Ancestral forms of most of these features are known to have existed during the Palaeozoic. They influenced sedimentation in that they controlled the margins of the structural and sedimentary basins throughout these times (Simpson, 1979a). The persistence of the forms is evidence that they are a reflection of fracture zones within the basement, that have been repeatedly reactivated by regional tectonic forces to produce structures of similar orientation throughout the succession.

Kent (1974) compiled for southern Saskatchewan the many, mutually perpendicular, linear features with a dominant northwest-southeast trend (Fig. 2). These were recognised by differences of topographic expression on air photographs, and by subsurface data, mainly isopach and structure contour maps. He believed that these represent zones of weakness, marking the boundaries of juxtaposed basement blocks. According to Thomas (1974), local uplifts and subsurface structures, such as the Nesson and Cedar Creek anticlines, may have been formed in response to regional stresses, which caused simple shear coupling on the basement blocks.

A twin aeromagnetic and gravity anomaly, trending southwesterly through west-central Manitoba and eastern Saskatchewan, known as the Nelson River high, is believed to represent the boundary between the Churchill and Superior Provinces (Hajnal and McClure, 1977).

There is a major anomaly in electrical conductivity running through Saskatchewan, from the Churchill Province of the Canadian Shield to the southern Rockies of southeastern Wyoming (Alibi et al., 1975). Camfield and Gough (1977) suggested that this belt of very high conductivity traces a major fracture zone in the Precambrian basement, representing a Proterozoic continental collision zone or geosuture. Horner and Hasegawa (1978) have noted seismic activity in the area of this feature in southern Saskatchewan.

Solution-Generated Collapse Features

Salt deposits of the Middle Devonian extend northwards from mid North Dakota, through Saskatchewan and Alberta as far as the Northwest Territories. In Saskatchewan, where the thickness of the salt is approximately 180-220 m, the effects of multi-stage salt solution have produced both regional and local features. The chief effect of the salt removal has been the creation of structural lows in the form of large, depressed areas, elongated linear troughs or local circular depressions. These are accompanied by a subsequent draping of strata and anomalous thickening and thinning of the sequences.

The edge of the Prarie Evaporite formation in Saskatchewan has been modified by solution giving rise to relatively steepened fronts and re-entrants of the halite beds. There is a large salt-free depression in south-central Saskatchewan in the region of the Swift Current Platform. An extension of this salt-free area is present at the western edge of the study area. This is the Hummingbird Trough, a north-south trending structure (Fig. 16). The removal of salt created a relief of approximately 90-150 m in this area. It is bounded by prominent scarps at the salt edge to the northeast and northwest of the area, over which there is draping of younger strata (Christopher et al, 1971).

A belt of high electrical conductivity underlies the position of this trough and the eastern edge of the large salt-free area in south central Saskatchewan (Fig. 17). It occurs in the area of greatest known seismicity along this feature in Saskatchewan (Horner and Hasagawa, 1978). The location of these features suggests that these collapse structures are basement controlled.

Many smaller-scale solution-formed depressions are also present in Sascatchewan. Typical of these is the Rosetown Low, a steep-sided, fracture-bounded depression, covering four townships in west-central Saskatchewan. It has a relief of several tens of metres; salt removal occurred in post-Cretaceous time (DeMille et al, 1964). Christiansen (1967) has described fracture-bounded collapse structures from the Saskatoon area. In this case, solution post-dating the earliest glaciation has created a depression with a relief of approximately 198 m.

The linear nature of some of the northeasterly directed solution-generated structures and their parallel arrangement, reflecting the structural trends of the Churchill Province, suggest that many of these features are basement-controlled (Kent, 1973).

The Sub-Mesozoic Unconformity

After the deposition of the Mississippian carbonates the region was uplifted and subjected to prolonged erosion. This led to the development of a karstic trellis topography upon the exposed Devonian and Mississippian strata (Christopher et al., 1971). The linear solution depressions, which are typical of this topography, influenced the development of incised fluvial channel systems in these rocks.

These topographic features and those of the Jurassic-Cretaceous unconformity have influenced the deposition of the overlying sediments of the Mesozoic. The arrangement of the Mannville fluvial and fluviomarine channel sands was determined by the underlying network, developed at both unconformities (Christopher, 1974). This relationship is also evident within the Colorado succession. Simpson (1979a) states that Viking lithofacies were influenced by pre-Cretaceous palaeotopography in that tidal channels were cut into the bottom sediments draping the cuesta marking the erosional edge of the Mississippian carbonates in western Saskatchewan. It is worth noting that Mannville valley systems closely correspond to preglacial channels cut into the Cretaceous bedrock, and to the present-day drainage system in that area (Simpson, 1978).

Jones (1961) demonstrated the correspondance between elements of the pre-Cretaceous erosion surface and structural trends of the Viking Formation in western Saskatchewan. He believed that this was due to compaction of the sediments on the buried topography. This caused thinning of the Viking sediments over the highs or buried hills, thereby producing irregular, amoeboid or drape folding.

DETAILED STRATIGRAPHY

Definition of Correlation Surfaces

The correlation surfaces used in this report were determined by means of their expression on spontaneous potential (SP) and resistivity logs. The SP log distinguishes between permeable and non-permeable formations. Usually the SP curve consists of a more or less straight base line, corresponding to the shales, and deflections or peaks to the left, opposite permeable strata.

The resistivity log exhibits lower values across permeable rather than non-permeable formations. Low resistivity deflections opposite the permeable formations, are just to the right of the base line corresponding to the shale values. The main use of resistivity logs is to determine the boundaries of resistive formations. The resistivity curves shown bn this report are the lateral-type. These curves are usually adequate to indicate the position of resistive zones, while minimising the effect of various possible distorting factors (Stratton and Ford, 1950).

The SP curve may show a subdued response within permeable formations, where there is a high clay content. In the Viking Formation there are many interlaminated shales within the sandstones; these may be responsible for the low SP response, seen within the Formation in some wells. Examples are seen in Figure 5, most notably in wells 1, 2 and 8. Expressions of silty and sandy markers within the Big River and Joli Fou Formations are also commonly subdued on the SP log. These formations are usually correlated on the basis of the resistivity curve.

A major factor affecting the response of the SP curve is the salinity contrast between the formation fluid and the drilling mud. Where the mud resistivity is very close to the formation-water resistivity, the SP becomes so subdued that the expression is virtually nil. An example of this is seen in Figure 7, well number 4. Where mud resistivity is less than the formation-water resistivity the SP curve is reversed. This is quite common in the Viking and adjacent formations. This SP reversal is seen in Figure 6, in wells 1, 2, 3, 4 and 6, in Figure 7, in wells 9, 13 and 14, and in Figure 5 in well number 4. Because most drilling fluids are comparatively fresh, this indicates that the formation-fluids in these wells consist of fresh rather than salt water (Stratton and Ford, 1950).

Occasionally the "picks" of the upper and lower surfaces of the Viking Formation are at different levels on the SP and resistivity logs. An example of this is seen in Figure 5, well number 8. In this case the "pick" is made on the basis of the resistivity curve alone. According to Doll (1948) anomalies on permeable beds on SP logs tend to spread above and below the permeable beds so that permeable zone boundaries are not determined. The resistivity curve is, therefore, a more reliable indicator of formation boundaries.

The surfaces used in this report are the upper surface of the Mannville Group, the upper and lower surfaces of the Viking Sandstone Formation and the lower surface of the Second White-Speckled Shale, which is taken as a stratigraphic datum for the sections. A typical well log for this area is shown in Figure 3.

The top of the Mannville Group, as determined by Christopher (1974), is taken at the top of the uppermost Pense sandstone, which

Socony Central Del Rio West Ratcliffe 22-13

LSD 13-22-1-16 W2

KB 712m

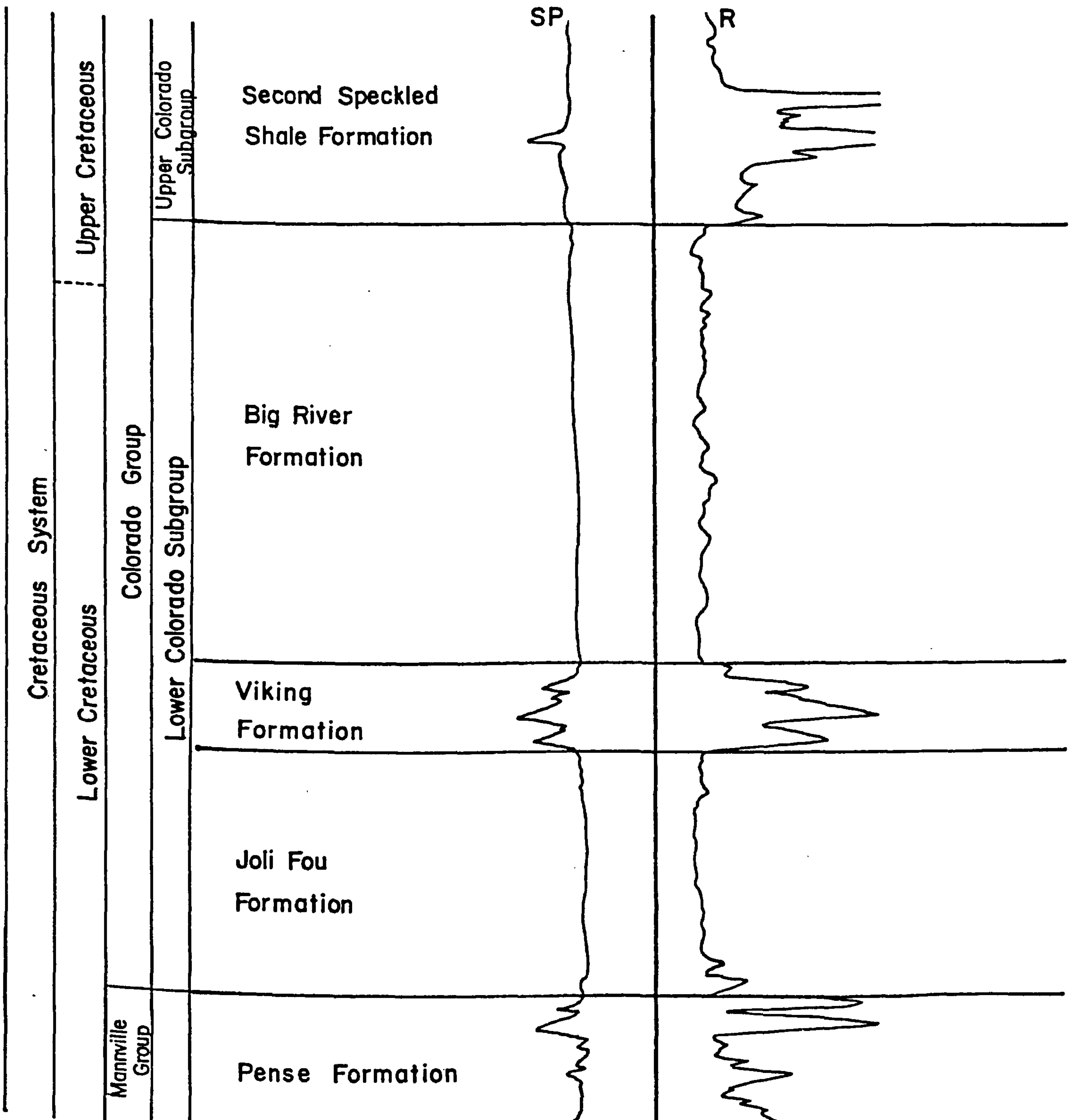


Figure 3

Well-Log

usually gives a sharp response on the resistivity and spontaneous potential profiles. In the southern part of the study area a thin sandstone unit, known as the Basal Colorado sand, is present within the Joli Fou Formation, usually within 10 m of the base of the Joli Fou. It is distinct from the Pense Formation, in that it has a much more subdued response on both the SP and resistivity curves. Also, it does not show as good continuity between wells as the Pense sands.

The base of the Viking Formation is erosional and usually has a sharply defined response on the resistivity profile, marking the junction between the sandstone and the marine shales of the Joli Fou Formation. The top of the sandstone tends to be more gradational on both the resistivity and spontaneous potential curves ; usually a point was taken that is transitional between a typical sandstone and a typical shale response. These are usually no more than two metres apart. The shaly chalks and calcareous shales at the base of the Second White-Speckled Shale Formation usually show a sharp deflection on both profiles.

Price (1963) used a different criterion in his determination of the upper and lower boundaries of the Viking Formation, than is used in this report. He used arbitrary boundaries corresponding to the upper and lower boundaries of the Viking sand in a standard section. This section, which he considered to be the thickest in Saskatchewan, is in the Shell Albercan Govenlock 1 well (Township 1, Range 28 W3). He traced these upper and lower Viking boundaries from this well into southeastern Saskatchewan by using the silty/sandy marker horizons within the Joli Fou and Big River Formations, which he found to be persistent over long distances.

This method of determination places the shale sections above and below the Viking Formation in eastern Saskatchewan, which are the direct stratigraphic equivalents of the thick Viking sands in western Saskatchewan, in his Viking Formation. This report regards the Viking Formation in this area as consisting solely of the regressive sandstone sequence, which separates the underlying and overlying transgressive Joli Fou and Big River shale.

The Mannville Group

The term Mannville Formation was first used by Nauss (1945), who applied it to Lower Cretaceous sediments underlying the Colorado Shales in east and central Alberta. This was later raised to Group status and expanded into Saskatchewan by Badgley (1952). Maycock (1967) divided the Group in southwestern Saskatchewan into a lower, heterogeneous, continental sequence, which overlies a river-dissected, Jurassic-Cretaceous erosion surface, and an upper marginal, marine sequence. Christopher (1974) divided the Group in southwestern Saskatchewan into (1) The Success Formation, the oldest Formation and consists of lacustrine and fluviatile clastic deposits. (2) The Cantaur Formation, consisting of lower fluviatile deposits succeeded by upper fluvio-deltaic deposits. (3) The Pense Formation, comprising mainly shallow marine clastics.

The Pense Formation at the base of the Colorado Group, gives way to the silts and black shales of the Joli Fou Formation.

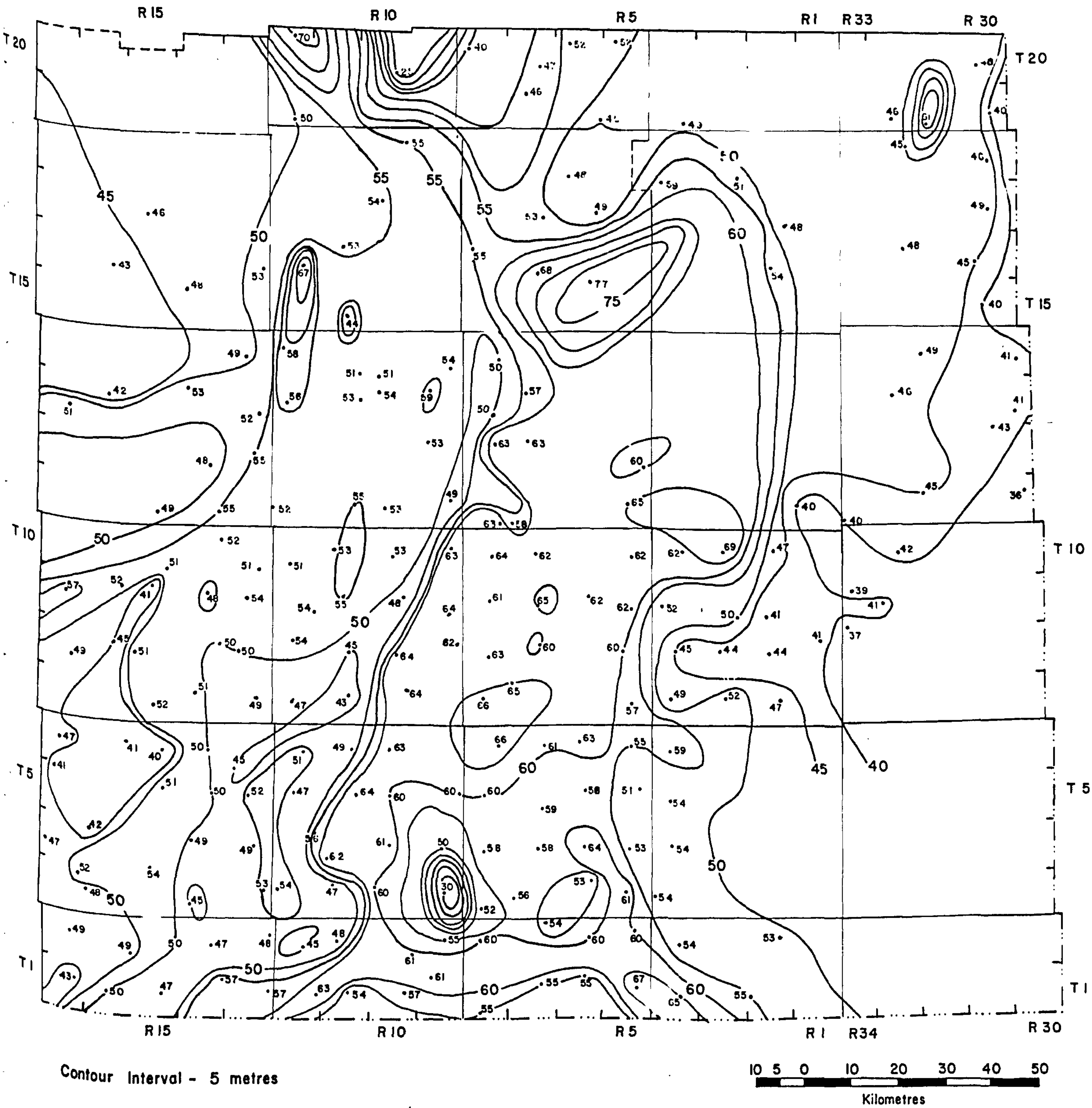
The Joli Fou Formation

The Joli Fou Formation was first named by Wickenden (1949), who described it in eastern Alberta. The Joli Fou Formation in Saskatchewan is a direct equivalent of this. It has been described in southeastern Saskatchewan by Price (1963) and over all of Saskatchewan by Simpson (1975).

The unit consists of dark grey, non-calcareous mudstones and shales, containing thin layers of siltstones and shaly sandstones. It has a widespread distribution throughout the Western Canadian sedimentary basin, extending from southern Alberta, where it is replaced by the lowermost Bow Island Sandstones, to western Manitoba where it is in continuation with the mudstones of the lower part of the Lower Ashville Formation. According to Simpson (in press a) it attains a thickness of 61 m in south-central Saskatchewan. In eastern Saskatchewan, Price (1963), described it as decreasing northwards in thickness from 45 m at the forty-ninth Parallel to 24 m at township 30.

Figure 4 shows the thickness of the Joli Fou Formation within the study area. It is widespread and continuous, forming broad, rather general north-south trending bands of varying thickness. It is generally thickest between Ranges 3 W2 and 10 W2, where it forms a band as far north as Township 18, and has an average thickness of between 60 and 65 m. To the west of this area, the formation is an average of about 50 m thick and in the east about 40 m. Within these broad trends there are many irregularities of either increased or decreased thickness. A maximum thickness of 77 m is seen at Township 16 Range 6 W2 and a minimum of 25 m at Township 20 Range 10 W2. Although common in occurrences these variations are limited in area.

Figure 5 shows a northeast-southwest stratigraphic section across the area. Within this section, the Joli Fou maintains a constant thickness of about 50 m. In areas where the Viking Formation is absent, the Joli Fou succession contacts the Big River Formation to form an undifferentiated Lower Colorado sequence. This is seen in the two most northerly wells of this section.



ISOPACH MAP - JOLI FOU FORMATION

Figure - 4

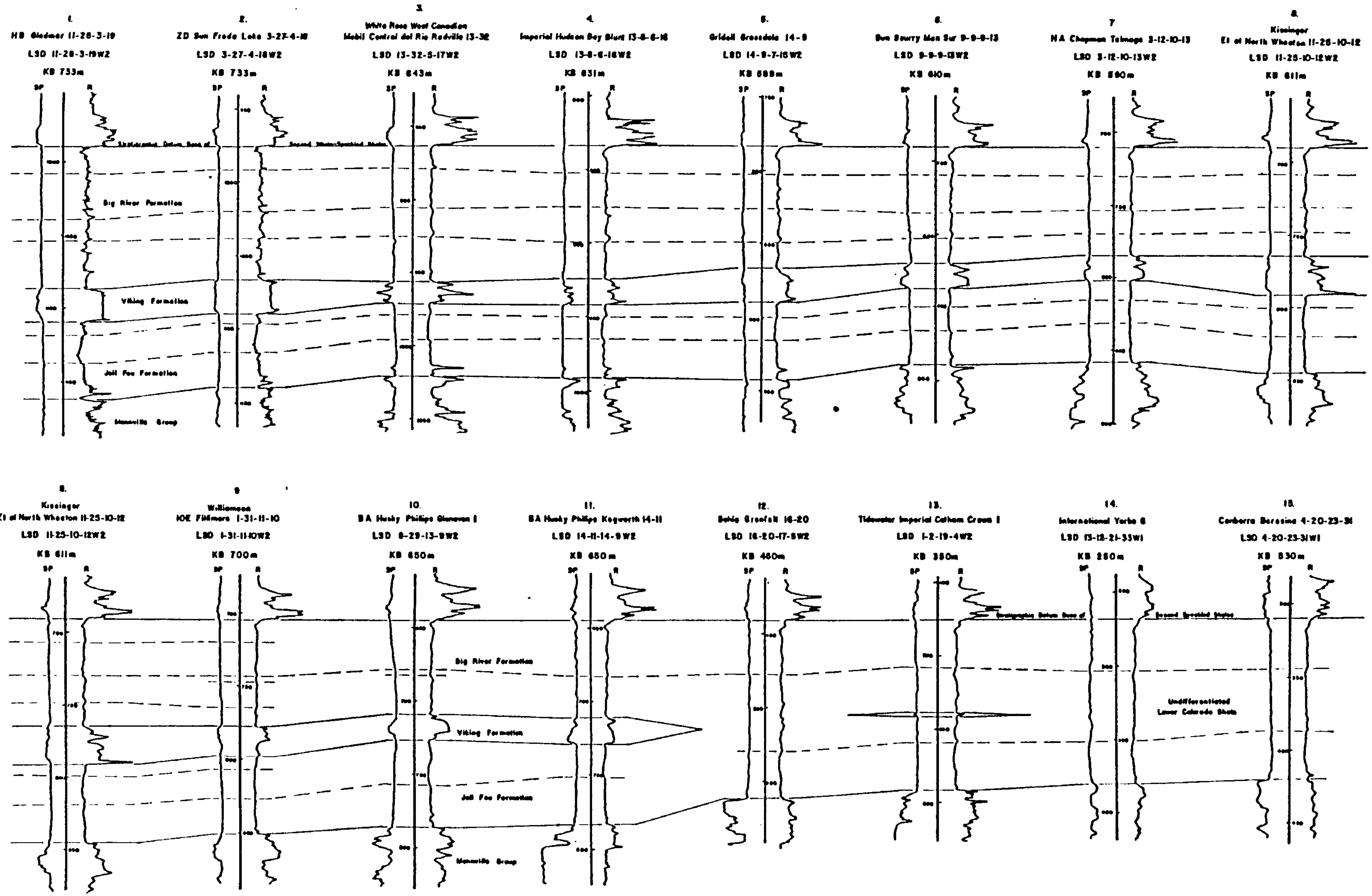


Figure - 5 Southwest - Northeast Stratigraphic Cross Section.

Many sandy/silty intercalations are present, some of which are quite persistent. In Figure 5, one of these is correlated within the Joli Fou Formation from well number 1 to well number 11, a distance of approximately 160 km. In the southern part of the section a sandy unit occurs at the base of the Joli Fou Formation. This unit has a maximum thickness of 8 m at Township 3 Range 19 W2, and thins northward to nothing at Township 9 Range 13 W2. This corresponds to the Basal Colorado Sand, a well sorted, fine- to coarse-grained sandstone with interbedded silts, shales and conglomerates, described by Simpson (1975 ; 1979a).

It occurs sporadically at the base of the Joli Fou Formation in southern Alberta, southern Saskatchewan and parts of northern Montana and North Dakota, where it has an average thickness of 6.5 m with a maximum thickness of 8 m. This sandstone is restricted to the southwest of the study area. It is also seen within the stratigraphic sections shown in Figures 6 , 7 and 8. In these sections it is absent east of Range 9 W2 and north of Township 9. The unit occurs always within 10 m of the base of the Joli Fou Formation in this area. The thickest developments are in the west, as is seen in Figures 5 and 6. It thins towards the east, the average thickness being less than 5 m.

To the west of the study area in south-central Saskatchewan the Joli Fou Formation is divided into an upper shale and a lower Shield-derived, fluvio-marine sandstone, called the Spinney Hill Member. This is thought to have been formed in an estuarine delta on the eastern shelf of the Colorado Basin (Simpson, 1975). It is lobate in form with a maximum thickness mf 36 m, and interdigitates with the Joli Fou Shale.

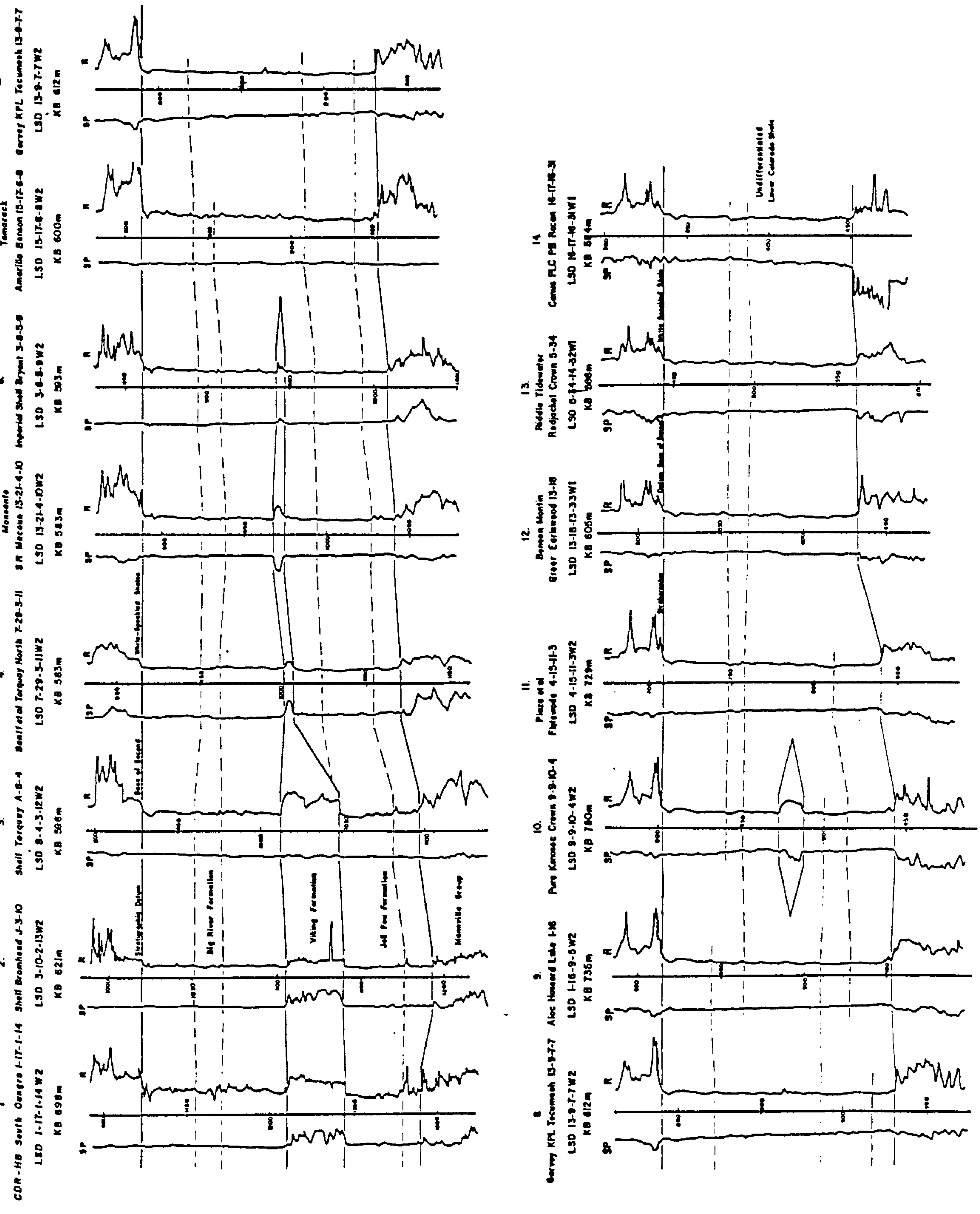


Figure - 6 Southwest - Northeast Stratigraphic Cross Section.

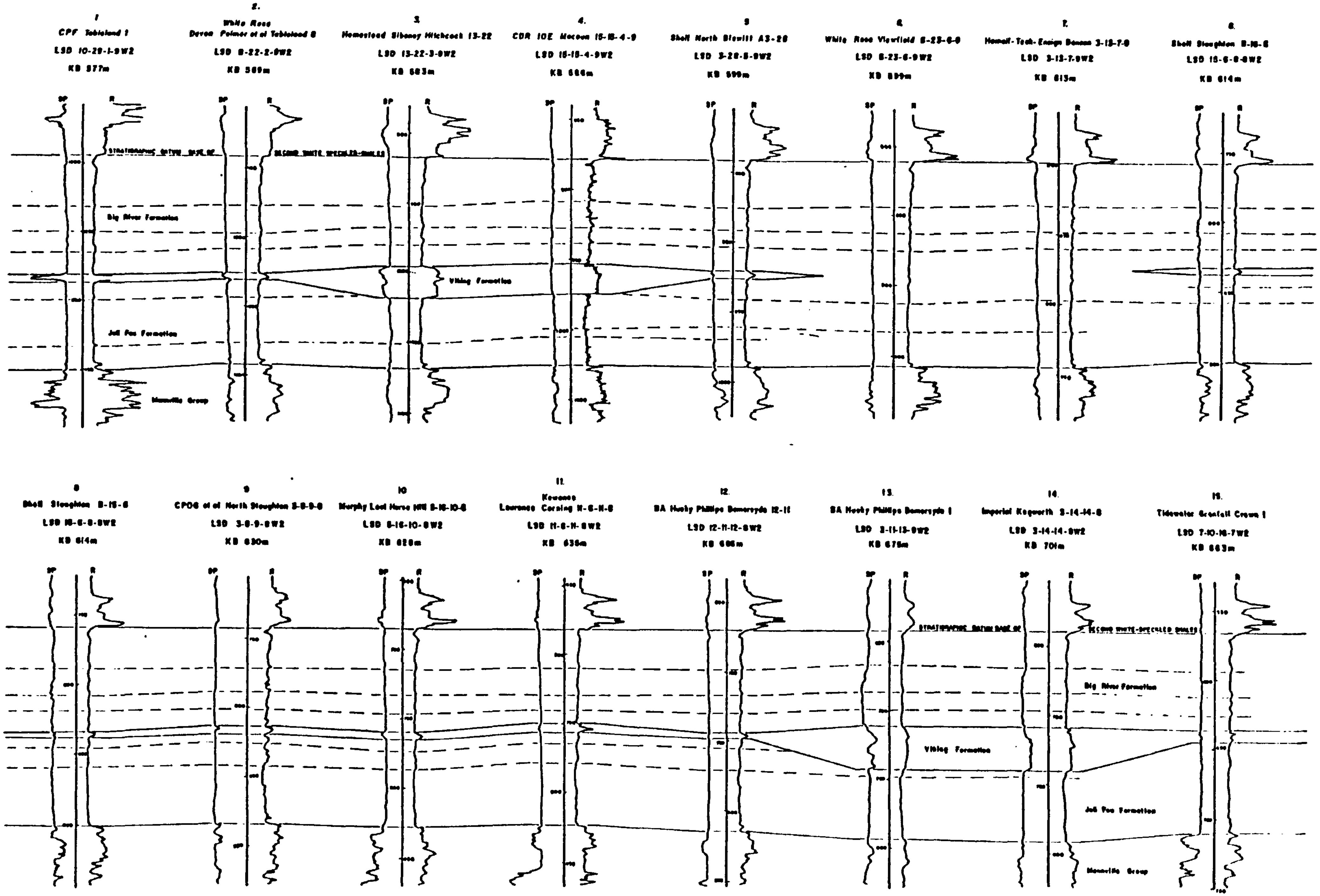


Figure - 7 South - North Stratigraphic Cross Section.

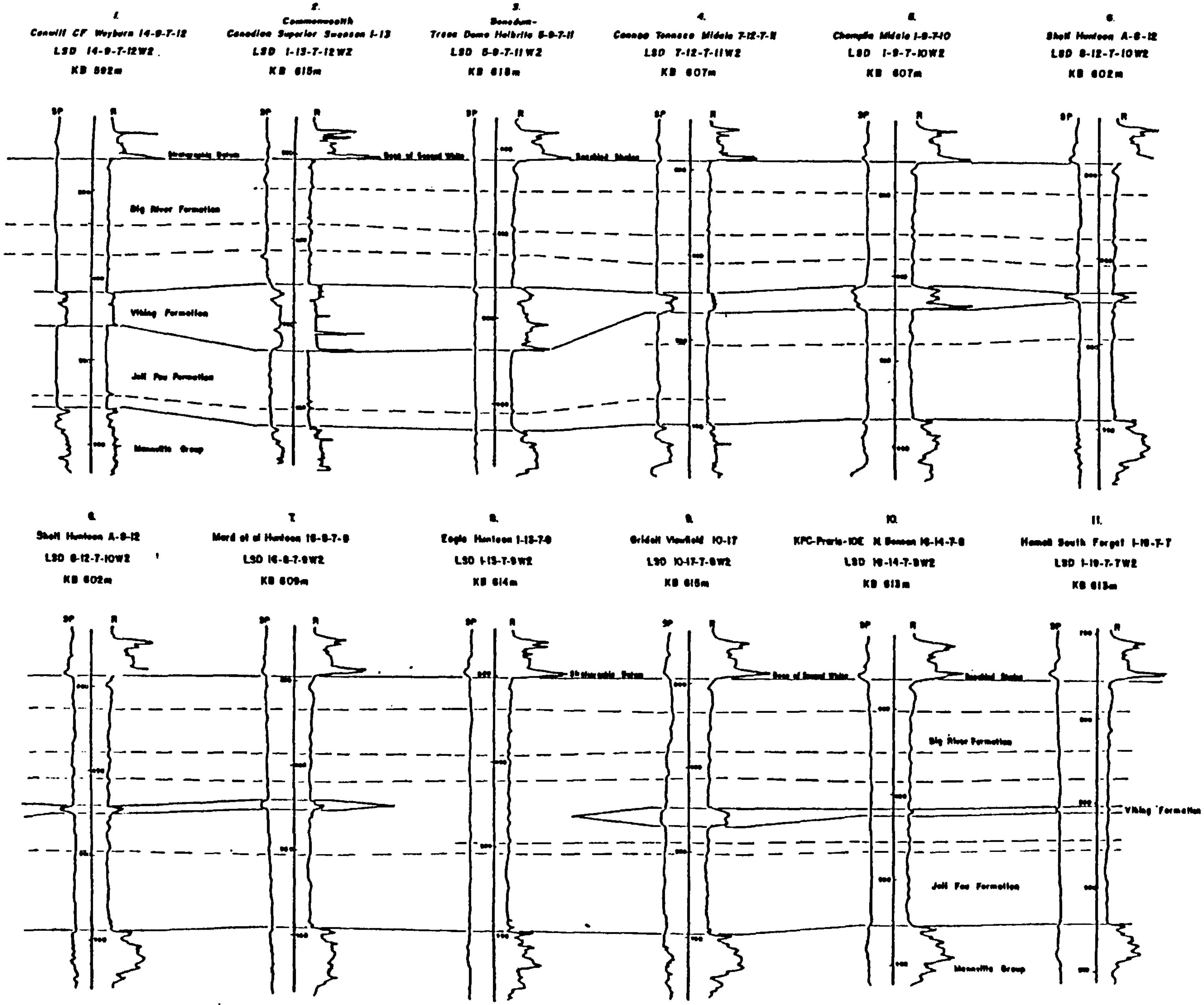


Figure - 8 West - East Stratigraphic Cross Section.

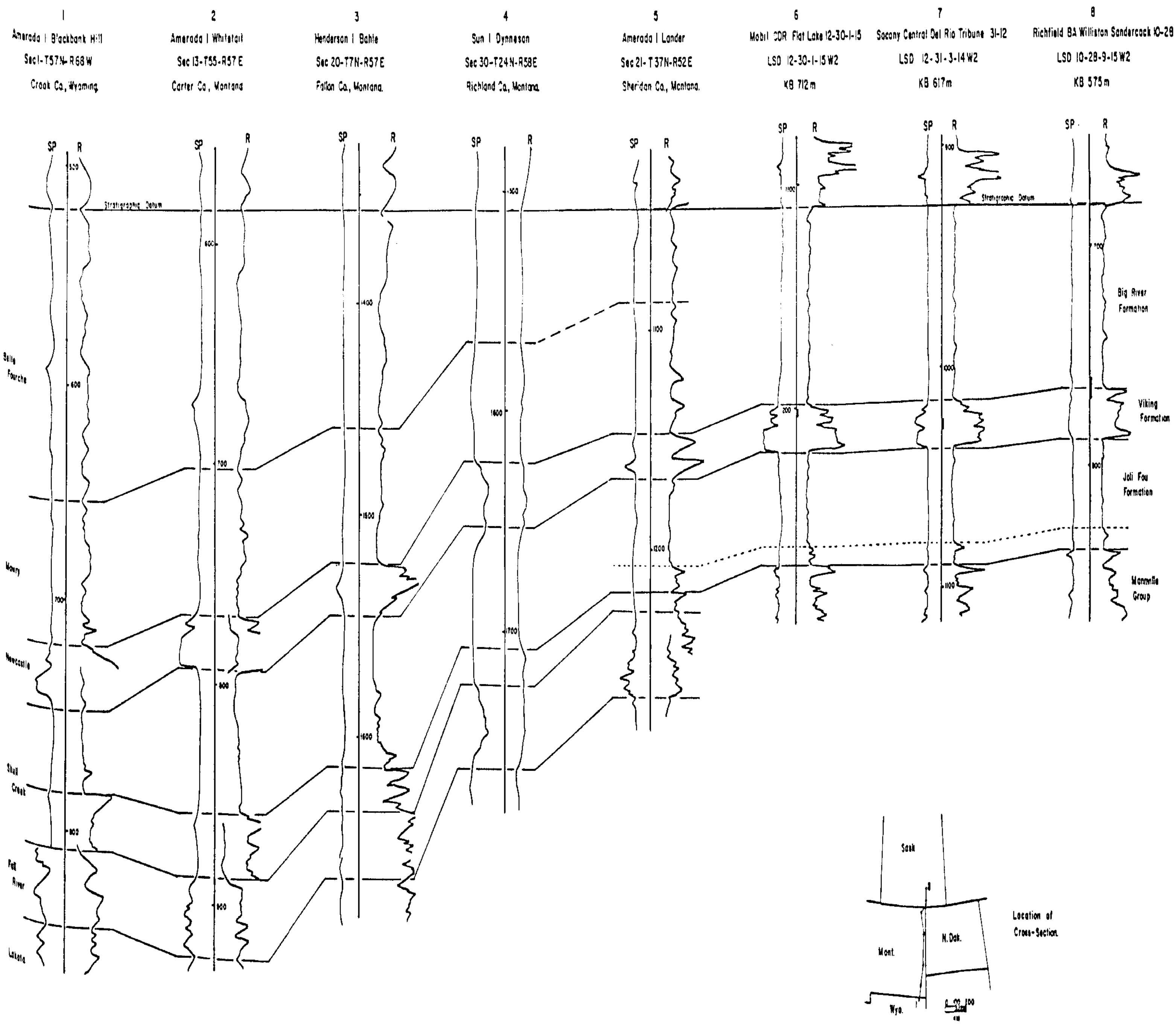


Figure - 9 South - North Stratigraphic Cross Section, N. Wyoming to S.E. Saskatchewan.

In Montana and North Dakota the Joli Fou Formation is represented by the Skull Creek Shale. This is composed of black shale, containing thin lenticular sandstones and siltstones near the top and at the base (Wulf, 1962). It is transitional with the underlying Fall River Sandstone and in sharp erosional contact with the succeeding Newcastle Sandstone (Hansen, 1955).

The relationship between the Formations is illustrated by a stratigraphic section, extending from northeast Wyoming through eastern Montana into southeastern Saskatchewan, shown in Figure 9. The Skull Creek Shale is slightly thicker in south central Montana, where it is between 60 and 70 m thick, than in southeastern Saskatchewan. It thins to 35 m in northeast Wyoming. Thin sandy and silty units, similar to those found within the Joli Fou are present within the Skull Creek Shale. Well developed sandy and silty units, up to 8 m in thickness are present at the base of the Skull Creek in well number 5 at Township 37 N, Range 52 E, and in well number 3 at Township 7 N, Range 57 E. These appear to represent the southward extension of the Basal Colorado Sand in this region.

The Viking Formation

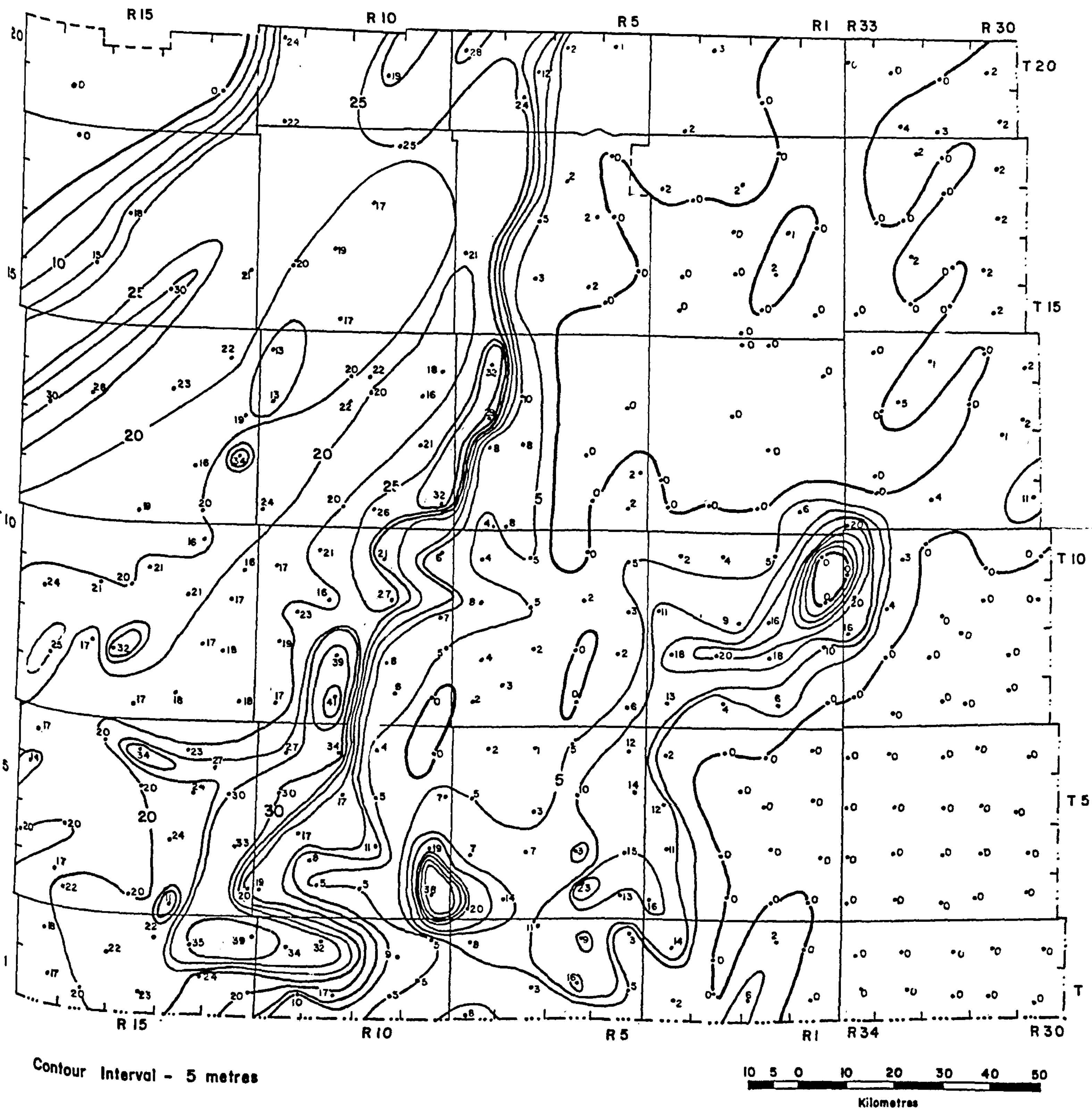
The Viking Formation in southeastern Saskatchewan (Fig. 10) is discontinuous and variable in thickness. It forms a broad northeast-southwest trending band, within which it is arranged generally as thin, elongate northeast-southwest trending bodies. It is absent at the northwest and southeast corners of the area.

The Formation in southeast Saskatchewan may be broadly divided into western and eastern parts. The western part is thick and continuous. It is broad and even with an average thickness of 20 m. This is interrupted by, local northeast-southwest trending bodies which are up to 30 m in thickness. There are also sites where the Formation thins to 11 m.

The Formation is thickest within a narrow, elongate area extending northeast from Range 13 W2 at Township 2 to Range 8 W2 at Township 14. This forms the eastern edge of the thick western portion of the Formation. In this area, the Viking Formation has a thickness of between 30 m and 40 m.

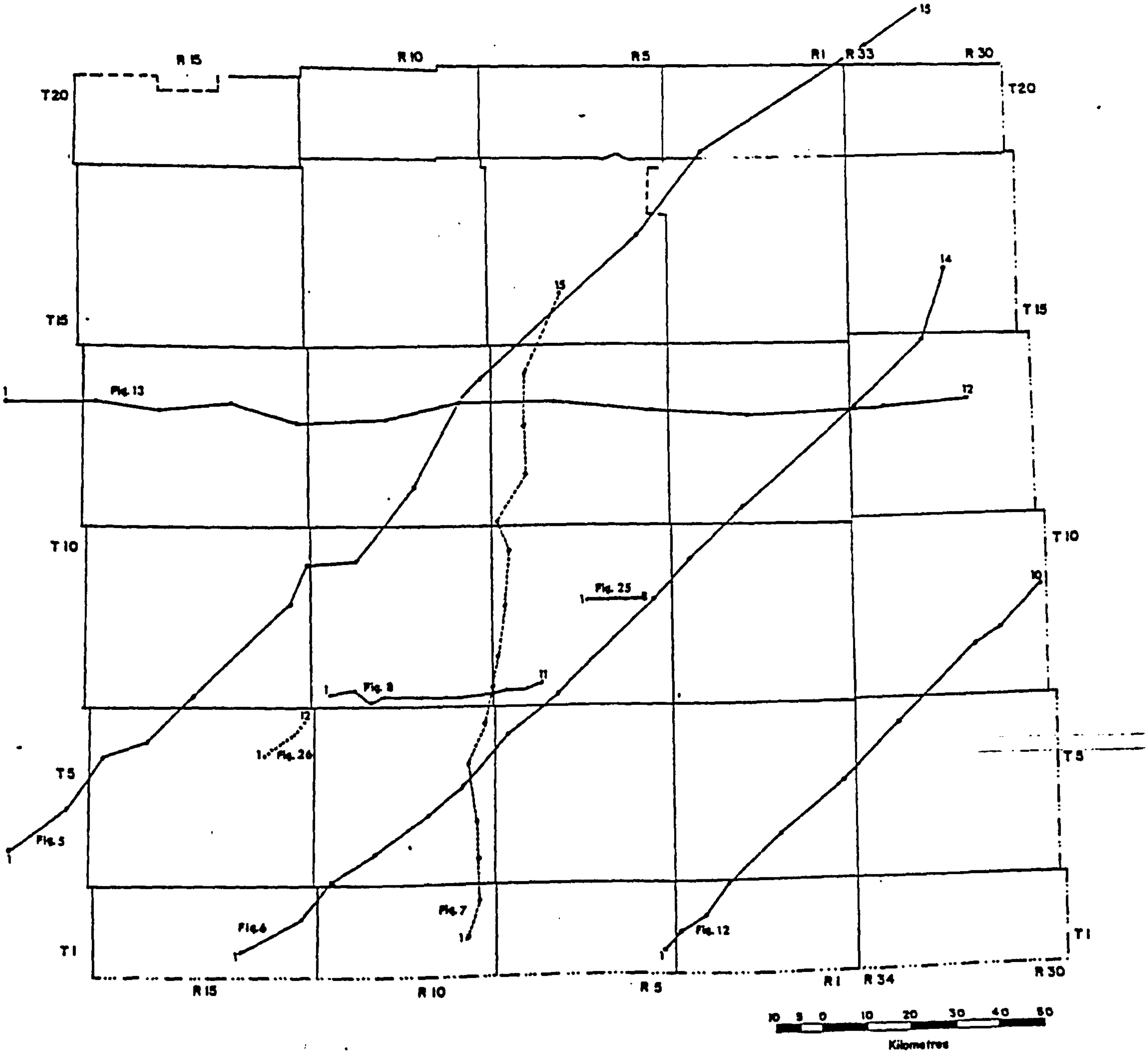
Immediately to the east of this thick, central body, the Formation undergoes a dramatic reduction in thickness. The sandstone becomes thin, discontinuous and uneven. In the northeast, the sandstone is largely absent and where present, forms a series of thin northeast-southwest trending lobes, less than 5 m thick.

In the south and east-central parts of the area, the Formation is thicker, but discontinuous. The thicknesses range generally from between 2 m and 15 m. It forms a poorly developed northeast-southwest trend of increased thickness extending generally from Range 6,



ISOPACH MAP - VIKING FORMATION

Figure - 10



Location of Cross Sections

Figure- 11

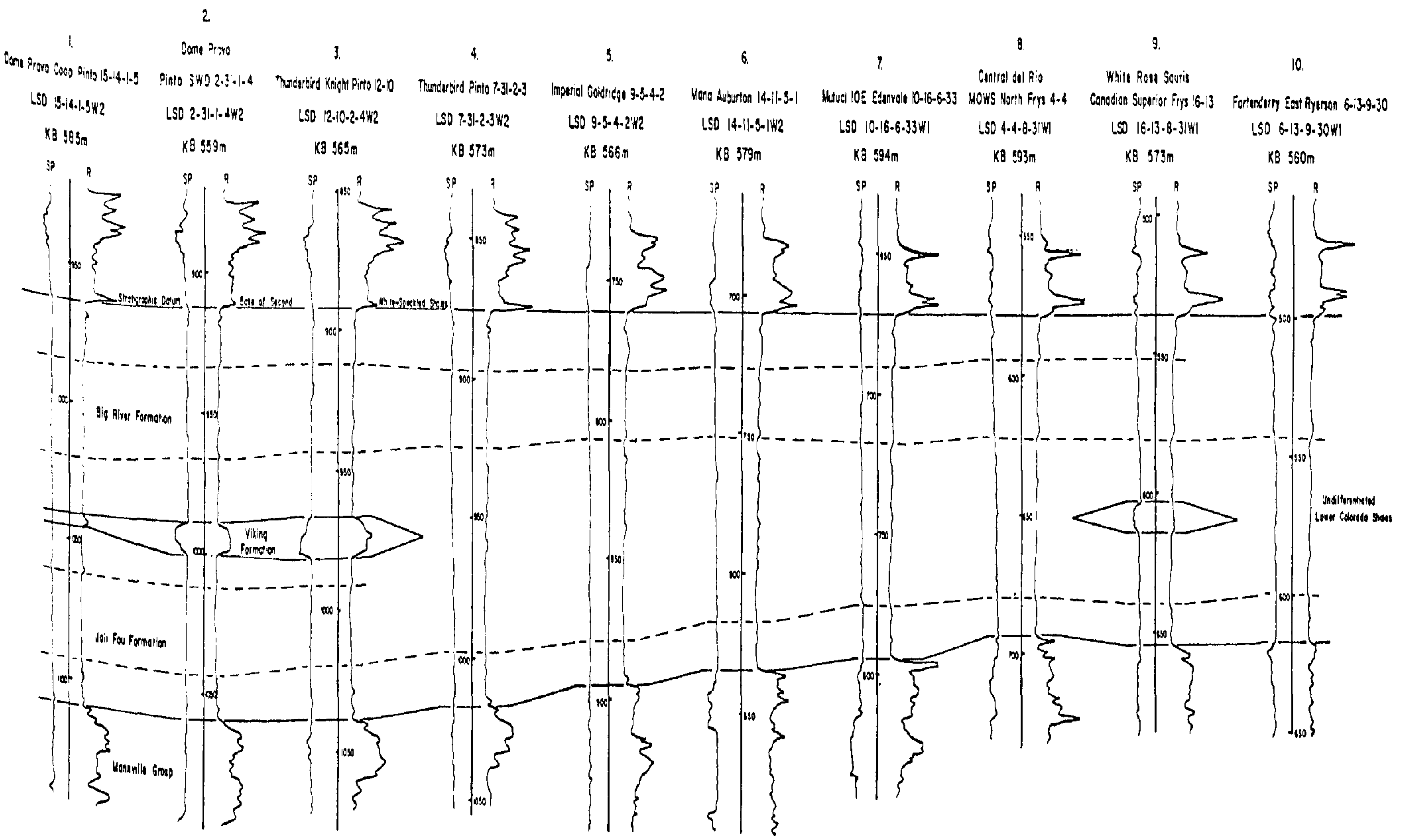


Figure - 12 Southwest - Northeast Stratigraphic Cross Section.

Township 1 W2 to Township 11, Range 33 W1. The maximum thickness is 23 m.

The general form of the Viking Sandstone within these areas of southeastern Saskatchewan is detailed by a series of stratigraphic sections. The position of these sections is shown in Figure 11. Three parallel northeast-southwest sections are presented in Figures 5, 6 and 12.

Figure 5 shows a section taken across the western and northeastern part of the area. It shows the thick, continuous nature of the Viking Formation in this region. The sand attains a maximum thickness of 26 m. It terminates abruptly between Township 14, Range 9 W2 and Township 17, Range 5 W2 and reappears as a thin lens at Township 19, Range 4 W2. Figure 6 shows the sharp Viking thinning in the central part of the area, from Township 3, Range 12 W2 where it is 34 m thick, to Township 3, Range 1 W2 where it is 6 m thick. The sandstone pinches out in a northerly direction, reappearing as an isolated body, 15 m in thickness, at Township 10, Range 4 W2. In the southeast corner of the area, in Figure 12, the Viking Formation is largely absent and where present, is less than 15 m in thickness. Figure 13 in the north, details the transition from the 35 m thick sand body, present at Ranges 12 W2 and 11 W2 to the thin discontinuous sands, less than 10 m thick at Range 7 W2.

A north-south section through the central part of the area is shown in Figure 7. The southern part of this section is taken through the eastern sand region. This shows the irregular nature of the sand. It is generally less than 10 m in thickness. At Townships 3 and 4 Range 9 W 2 it increases to 20 m yet pinches out to the north at

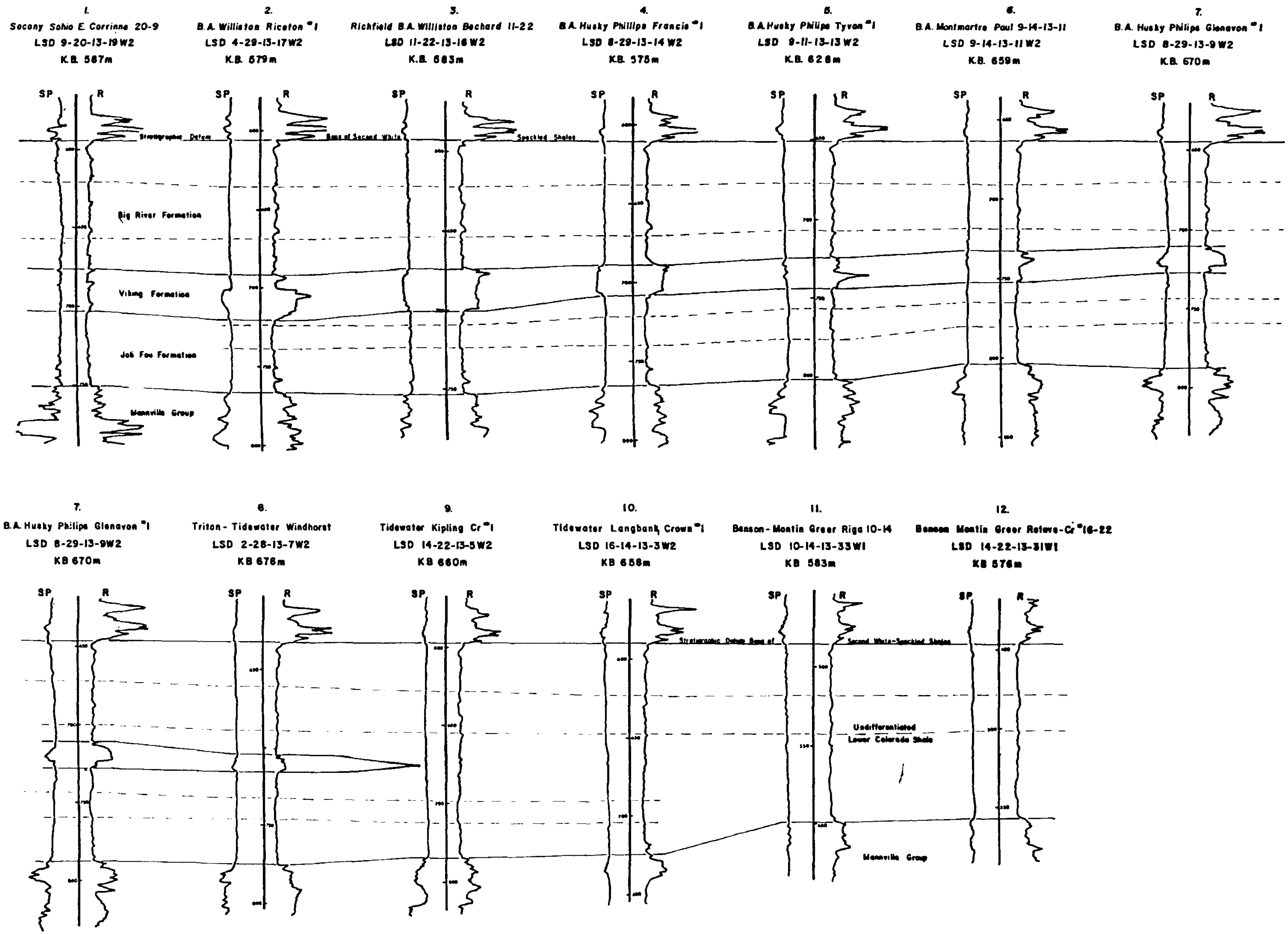


Figure - 13 West - East Stratigraphic Cross Section.

Townships 6 and 7 Range 9 W2. The section passes through the eastern edge of the thick western sandstone region at Townships 13 and 14, Range 8 W2 and shows an increase to approximately 30 m.

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According to Price (1963), the eastern Viking Formation pinches out to the west in the area of Range 23 W2. The western Viking sandstone extends as far eastwards as approximately Range 27 W2. Simpson and O'Connell (1979) have shown that the eastern Viking Sandstone may be stratigraphically higher than the western Viking Sandstone.

In southern Manitoba, the Viking is represented by the Ashville Sand. In southwest Manitoba this is a blanket sand generally less than 6 m in thickness and consists of interlayered mudstones, siltstones and fine-grained sandstones. In southeast Manitoba it forms irregular northwest-southeast trending belts and is up to 37 m in thickness. It is believed to have formed in tidal channels (Simpson, 1975).

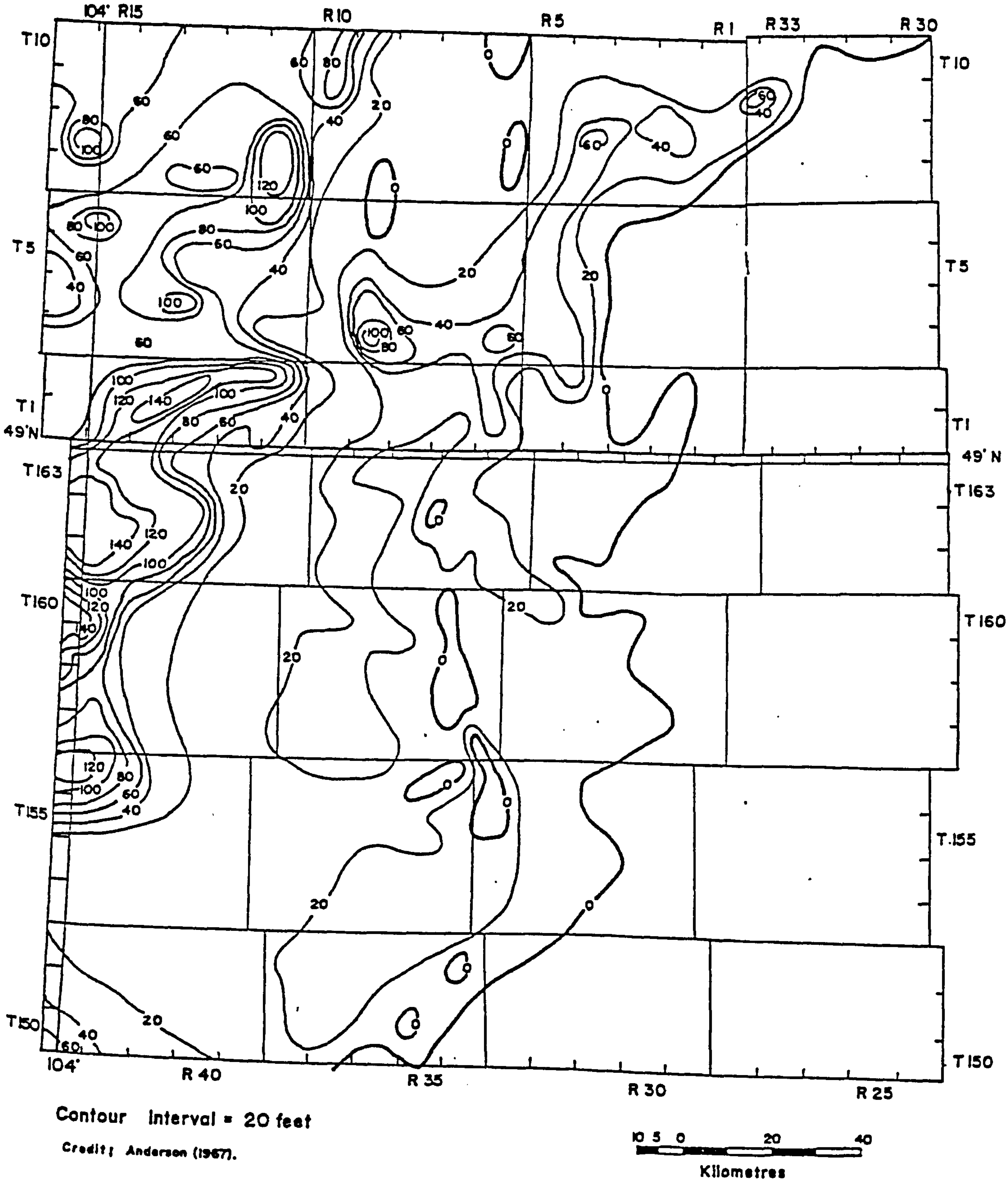
The stratigraphic equivalent of the Viking Formation in central Saskatchewan is the Flotten Lake Sandstone. This is a blanket-type sandstone up to 21 m thick. It consists of fine- to medium-grained sandstone with thin, intercalated siltstone and mudstone layers. It was laid down on a prominent, structural platform in this area and pinches out to the south (Simpson, 1975).

In North Dakota and Montana the Viking equivalent is the Newcastle or Muddy Formation which are described by Hansen (1955), Wulf (1962), Reishus (1968) and Anderson (1969) as a very fine-grained, light grey quartz sandstone containing beds of shale and silt with accessories of muscovite, biotite, chlorite, kaolinite and zircon, as well as, woody and carbonaceous fragments.

An isopachous map of the Viking Formation of southeastern Saskatchewan and the Newcastle Sandstone of northwest North Dakota, after Anderson (1969), is presented in Figure 14. This shows that the general trends of the sandstone in southeastern Saskatchewan, are similar to and continuous with those of northwest North Dakota.

In both areas the depositional trends are elongated in a north northeasterly-south southwesterly direction. The thick sand sheet of the western part of the area in southeastern Saskatchewan, is continuous to the south. The abrupt thinning of the sandstone at the eastern edge of this sheet occurs along a north northeast-south southwest line in both areas. In the central part of each area the sandstone has a thin, patchy distribution enclosing some areas of non-deposition. Local bodies of this sandstone in southeastern Saskatchewan, however, are between 40 and 60 feet (12 m and 18 m) thick. This is not seen in the adjacent area of northwest North Dakota. The sandstone is absent in the eastern parts of both areas.

Reishus (1968) and Anderson (1969) have proposed that the Nesson Anticline controlled the deposition of the Viking Formation in northwest North Dakota. The position of this anticline is shown in Figure 16. They believed that the source area for these sands was in the west, and that the anticline acted as a barrier to sand movement from this direction. This created the thick accumulation of sand on the western flank of the anticline. The thin, patchy distribution of the sand in the central part of the area corresponds to deposition along the crest of the anticline. The area to the east of the anticline was starved of sand.



ISOPACH MAP - Viking and Newcastle Formations;

Southeastern Saskatchewan & Northwest N. Dakota.

Figure - 14

This reconstruction is questionable, however, because Simpson (1975) has shown that the Viking Sandstone of eastern Saskatchewan is a body separate from the western Viking Formation, and is derived from an easterly source. The Newcastle of northwest North Dakota is in continuity with the eastern Viking and therefore is assumed to have an eastern source. Also, there is no evidence that the Nesson Anticline had a structural influence in southeastern Saskatchewan at that time. The similarity of the depositional trends in these areas at that time, however, shows that the depositional controls must have been essentially the same in both areas.

In southwestern North Dakota the Newcastle Sandstone is up to 40 m in thickness (Reishus, 1968) and is believed to represent deltaic deposition (Anderson, 1969). The Newcastle in eastern North Dakota forms a blanket sand thickening to the east. This is thought by Reishus (1968) to represent a shallow marine sand, deposited under near-shore conditions.

The stratigraphic section from northeast Wyoming into southeast Saskatchewan, shows that little variation in the form of the sandstone occurs between the Viking and the Newcastle Formations. The sandstone is continuous and regular throughout this, rather general, section. It thins slightly from 30 m in north and central Montana and northern Wyoming.

Wulf (1962) considered the Newcastle Sandstone in Wyoming and North and South Dakota to be a mixed continental/marine sandstone, deposited in deltaic channels. He classified the Newcastle Sandstone as an upper member of the Skull Creek Shale and placed a regional disconformity at its top. He considered the sandstone in the western

North Dakota and eastern Montana region to be above this disconformity and classified it as a lower member of the Mowry Shale. He called this the Dynesson Sandstone. This Dynesson Sandstone is, therefore, stratigraphically higher than the Newcastle Sandstone in west and central Montana, which is the southern equivalent of the western Viking Sandstone.

Accordingly the southernmost well in the section of Figure 9, the Amerada 1 Blackbank Hill well (sec 1-T 57N-R 68W) penetrates the Newcastle Sandstone, whereas the sand bodies to the north in the section include the Dynneson Sandstone. The disconformity has not been found by other workers. Its reality is supported, however, by the observation of Simpson and O'Connell (1979), that the eastern Viking Sandstone may be stratigraphically higher than the western Viking sandstone in Saskatchewan.

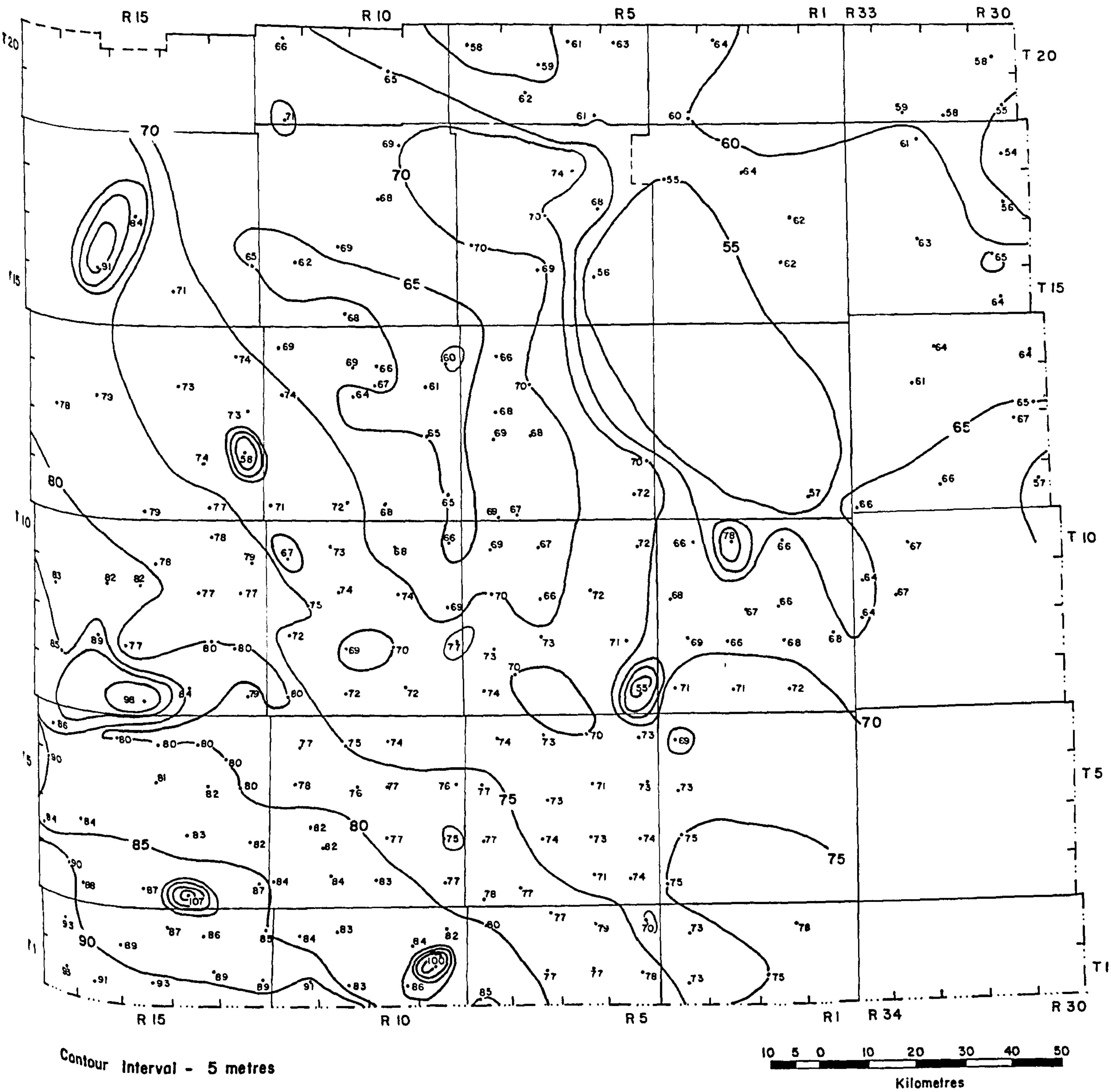
The Big River Formation

The strata between the Viking Formation and the Second Speckled Shales constitutes the Big River Formation. The first detailed description of this unit was made by Price and Ball (1971) in west central Saskatchewan who described it as a monotonous sequence of soft, dark grey, non-calcareous mudstones and shales. Thin, intercalated sandstones and siltstones are common.

The Big River Formation extends from southern Alberta, where it is replaced by the uppermost sandstones of the Bow Island Formation, across to southern Manitoba, where it is represented by the mudstones of the upper part of the Ashville Formation. According to Simpson (in press a), the Formation attains a maximum thickness of 150 m in southwestern Saskatchewan, thinning to 43 m in east-central Saskatchewan.

The distribution of the Big River Formation in southeastern Saskatchewan is shown in the isopach map of Figure 15, the isopachs form a series of broad northwesterly-southeasterly trends across the area, thinning towards the northeast. The Formation is thickest in the southwest corner where it averages between 85 to 90 m and generally thinnest in the northeast corner where it is, on average, between 55 and 60 m. A maximum thickness of 107 m is seen at Township 3, Range 14 W2 and a minimum of 54 m at Township 18, Range 30 W1. Local variations are quite restricted and are not as common or as pronounced as those in the Joli Fou Formation.

These trends are further illustrated by the stratigraphic cross-sections. Figure 5 shows the gradual northeastwards thinning of



ISOPACH MAP - BIG RIVER FORMATION

Figure - 15

the Formation and its contact in the north with the Joli Fou to form an undifferentiated Lower Colorado Sub-group. Internally the formation contains a great many thin intercalated sandstones and siltstones. These are generally more continuous and more easily correlated than those of the Joli Fou Formation and tend to decrease both in frequency and thickness towards the east. The Formation is in sharp contact with the overlying Second White-Speckled Shale.

Within the upper part of the Big River Formation in western Saskatchewan is the Fish-Scale Sandstone. This is a very fine-grained quartz sandstone, occurring in a graded sequence with mudstone and shales. Fish scales and bones are plentiful and the unit forms a widespread marker bed across the Great Plains Region. It rests on an erosive base, which marks the boundary between Upper and Lower Cretaceous strata. The unit is present in eastern Alberta, southwest Saskatchewan and Manitoba with an average thickness of 21 m (Simpson, in press a). The Fish-Scale Sandstone appears to be absent from the study area in southeast Saskatchewan and is not distinguished in any of the wells examined.

A sandstone that occurs within the upper part of the Big River Formation in east-central Saskatchewan has been described by Simpson (1979a) and named the Okla Sandstone. This is a very fine-grained, muddy, laminated sandstone, up to 15.2 m thick, and containing fish skeletal debris. It may correspond in part to the Fish-Scale Sandstone in this area.

A sandy equivalent of this formation occuring in west-central Saskatchewan is known as the St. Walburg Sandstone. It was laid down on the eastern shelf of the Colorado sea and was deposited probably as tidal sand ridges during the transgression (Simpson, 1975).

The relationship between the Big River Formation and its southern equivalents in Montana and North Dakota is shown in Figure 9. This shale thickens considerably to the south and is divided into the distinct Mowry and Belle Fourche Formations. The lower unit, the Mowry Shale is equivalent to the Big River Formation and is transitional with the underlying Newcastle Formation. Where the latter is absent there is an undifferentiated Skull Creek-Mowry Shale unit (Reishus, 1968).

The Mowry Shale is succeeded by the Belle Fourche Formation. This is a dark grey micaceous shale characterised by many bentonite layers (Hansen, 1955). The boundary between the Belle Fourche and Mowry Shales is erosional and corresponds to the Fish-Scale Sandstone, according to Price (1963). This boundary cannot be traced with confidence into southeastern Saskatchewan in the stratigraphic section of Figure 9. The Belle Fourche contains sandy and silty intercalations that thin sharply northwards in Saskatchewan and the Formation is in sharp contact with the overlying Greenhorn Formation.

The Upper Colorado Subgroup

The Upper Colorado Subgroup is a marine, transgressive sequence up to 183 m thick in southern Saskatchewan. The sequence is initiated by a grey calcareous shale Formation, rich in coccoliths and containing subordinate sandstones and siltstones. This is known as the Second (Lower) White-Speckled Shale. This is separated from the lithologically similar First (Upper) White Speckled Shale by an intervening dark, non-calcareous, unnamed Shale. These units represent a transgressive sequence, thinning towards the northeast (Simpson, 1975).

The major sandy units of the Upper Colorado occur in the upper part of the sequence. In eastern Saskatchewan and western Manitoba the Boyne Sandstone is found. In southwestern Saskatchewan and southeastern Alberta the Medicine Hat Sandstone occurs approximately 30.5 m below the top of the Colorado Group. It is a fine-grained sandstone up to 12 m in thickness and is overlain by the First White-Speckled Shale it shales out in west-central Saskatchewan (Simpson, 1979b).

Within the dominantly argillaceous Upper Colorado sequence in northern Montana, three main sandstone units occur. These are the Phillips Sandstone within the Greenhorn Formation, the Bowdoin Sandstone within the Carlile Formation and the Martin Sandy zone within the Niobrara Formation. Outliers of these sandy units are found in Saskatchewan (Simpson, 1979).

DETAILED STRUCTURE

The main tectonic elements of southeastern Saskatchewan are shown in Figures 16 and 17. At the western boundary of the study area is the elongate north-south trending syncline, the Hummingbird Trough, underlain by the zone of high electrical conductivity. The Nelson River Gravity High is present in the northeast corner of the study area. To the south of the area in northwest North Dakota is the north-south trending Nesson Anticline. A number of linear structural trends have been defined within the area by various authors.

Structure contour maps have been drawn on the upper and lower surfaces of the Lower Colorado Subgroup (Figs. 18 and 19), and the upper and lower surfaces of the Viking Formation (Figs. 20 and 21). These contours display a regional west northwesterly strike and a southerly dip that steepens in the southern part of the area. The base of the Lower Colorado Subgroup dips 4.1 m/km, south of Township 10, whereas to the North the dip decreases to 2.3 m/km. The upper contact of the Lower Colorado Subgroup dips less, being 3.8 m/km south of Township 10, and 2.2 m/km north of this.

Solution-Generated Collapse Features

The main effects of salt-solution upon the overlying sedimentary cover are as follows: (1) it creates a structural depression, caused by collapse of the post-evaporitic strata; (2) it produces anomalously

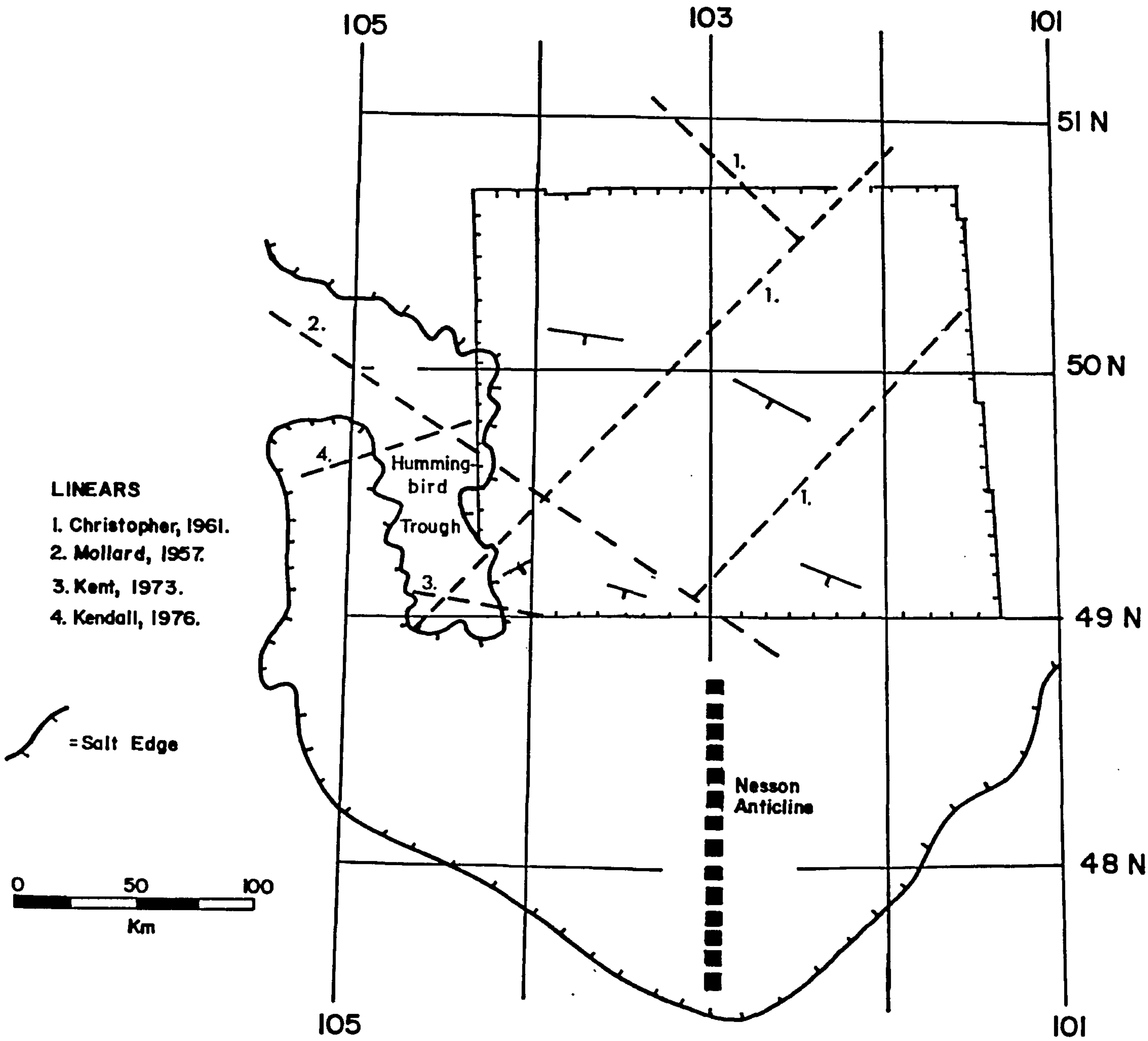


Fig. 16 Structural Elements in Southeastern Saskatchewan and Adjacent Areas.

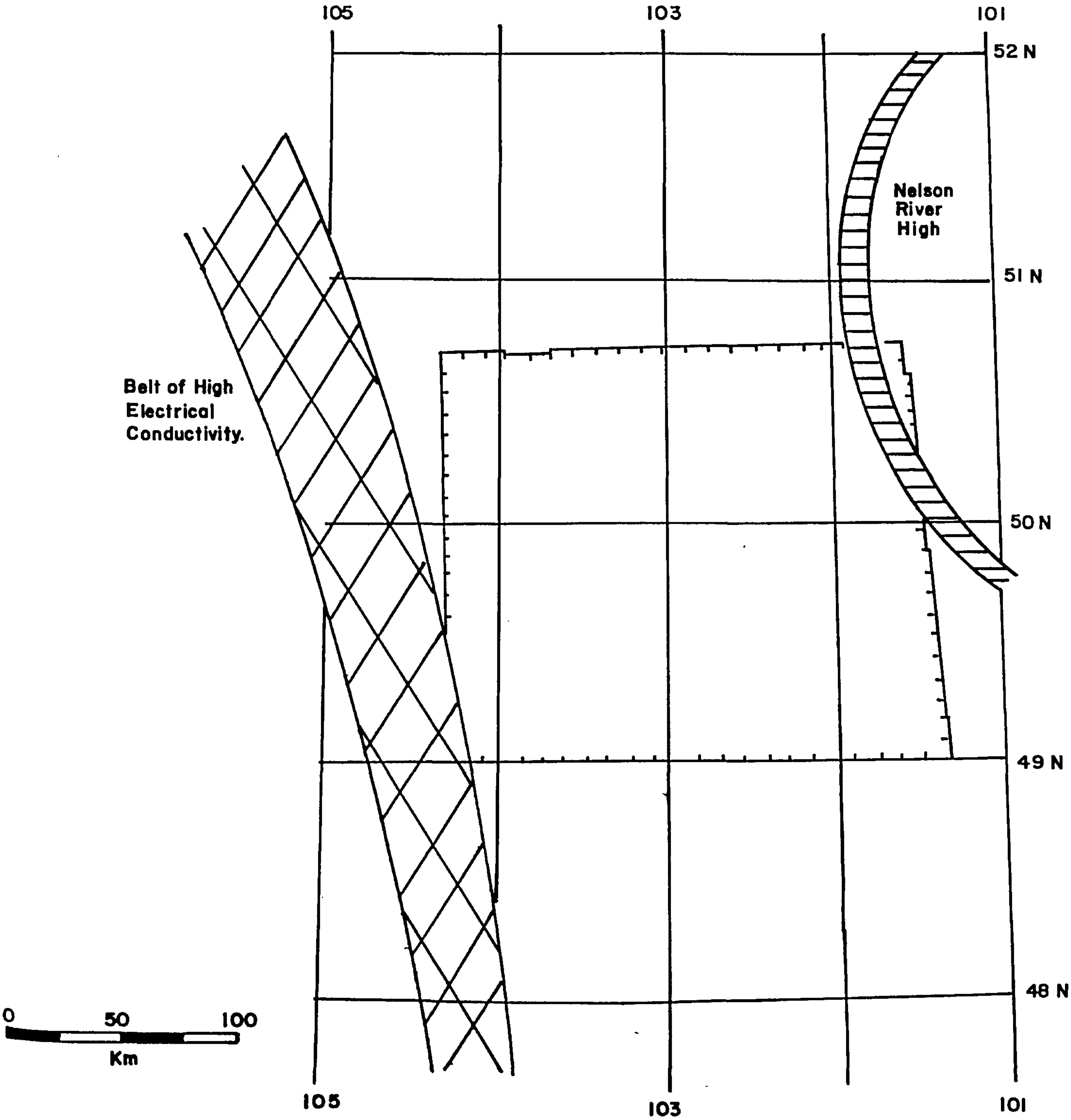
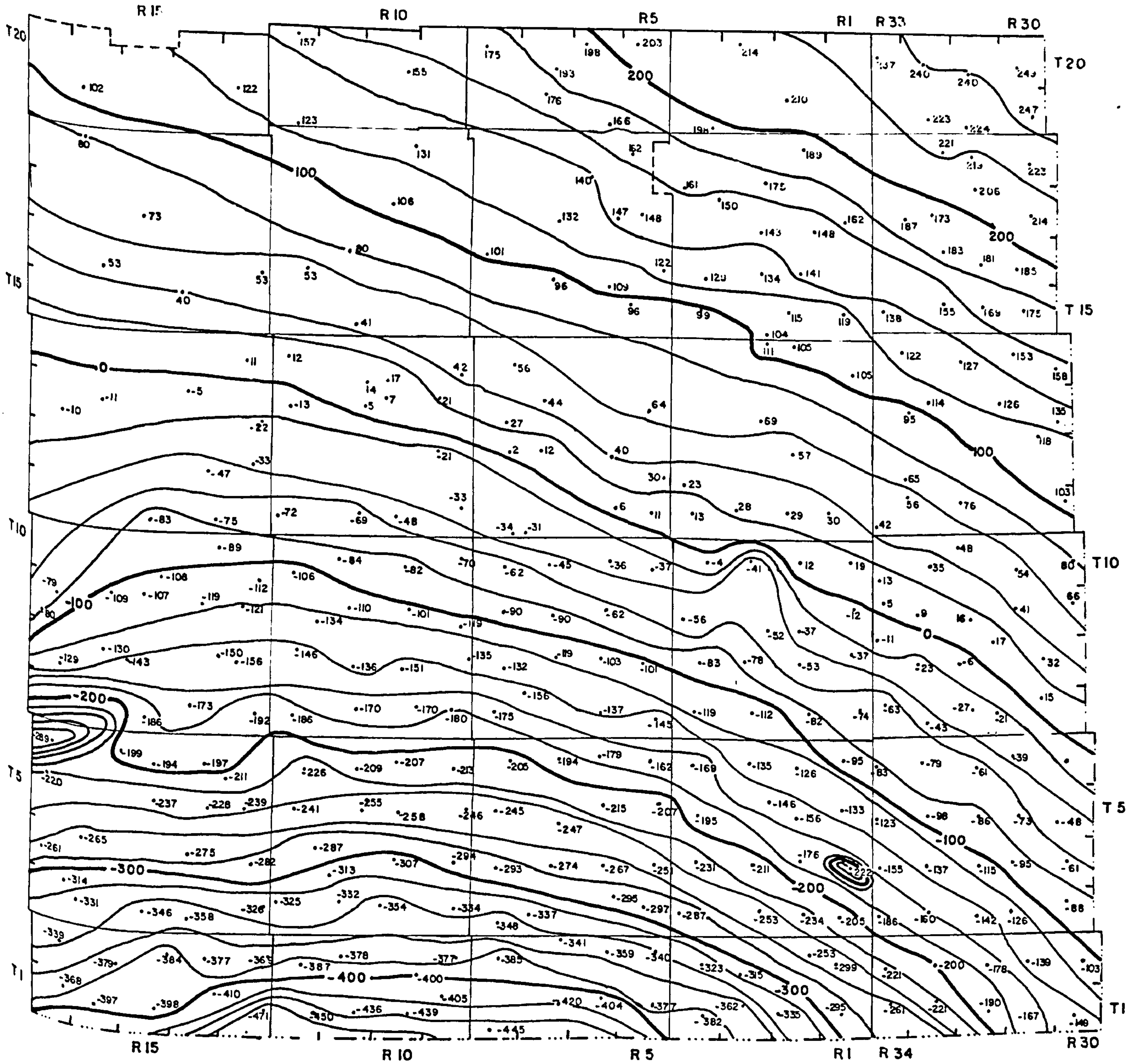


Fig. 17 Position of the Nelson River Gravity High and the Belt of High Electrical Conductivity in Southeastern Saskatchewan and Adjacent Areas.



Contour Interval - 20 metres

Structural Datum = Sea Level

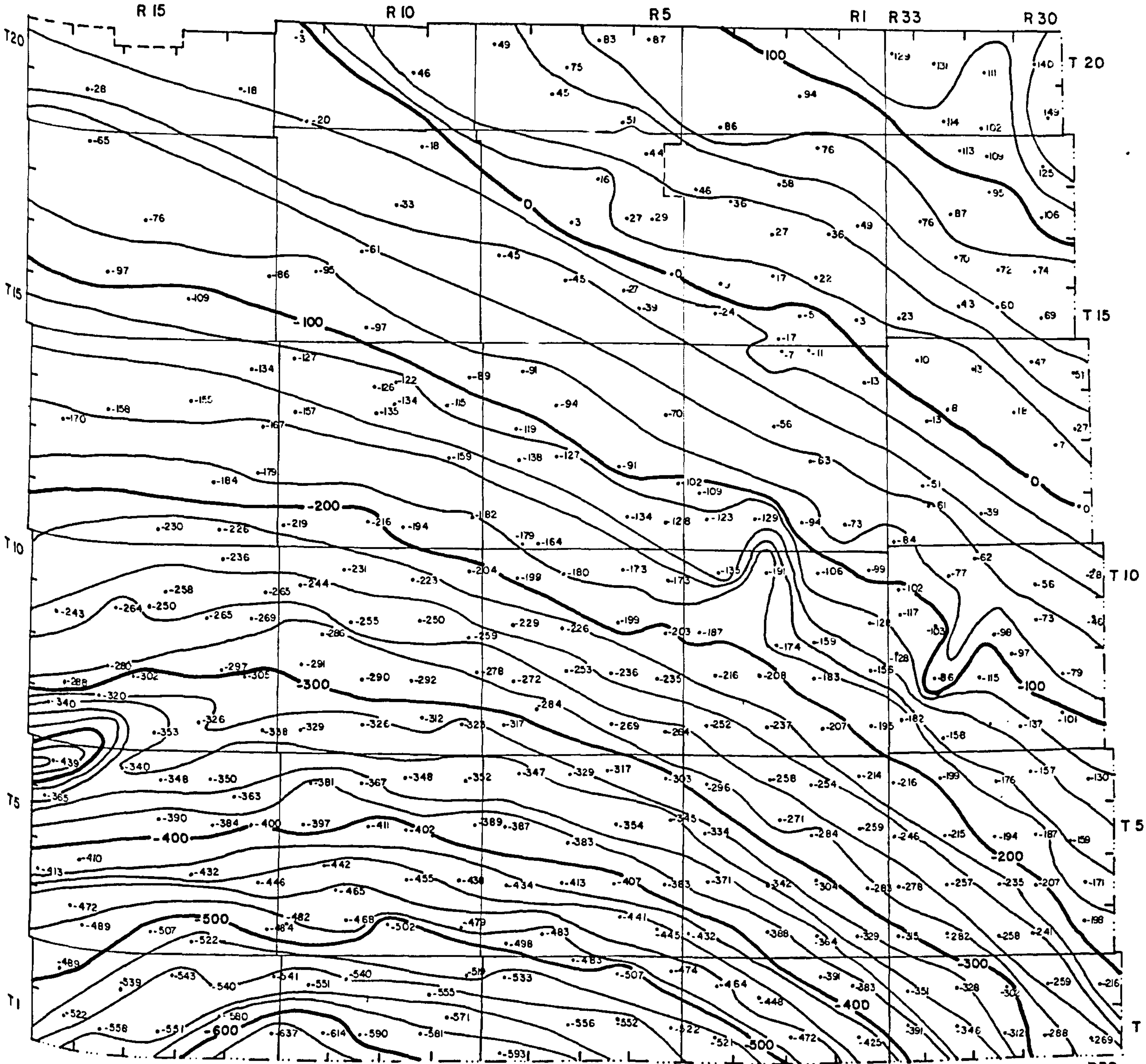
10 5 0 10 20 30 40 50

Kilometres

STRUCTURE CONTOURS

TOP OF LOWER COLORADO SUBGROUP

Figure - 18



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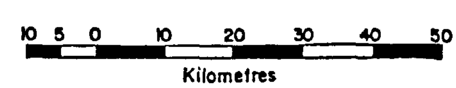
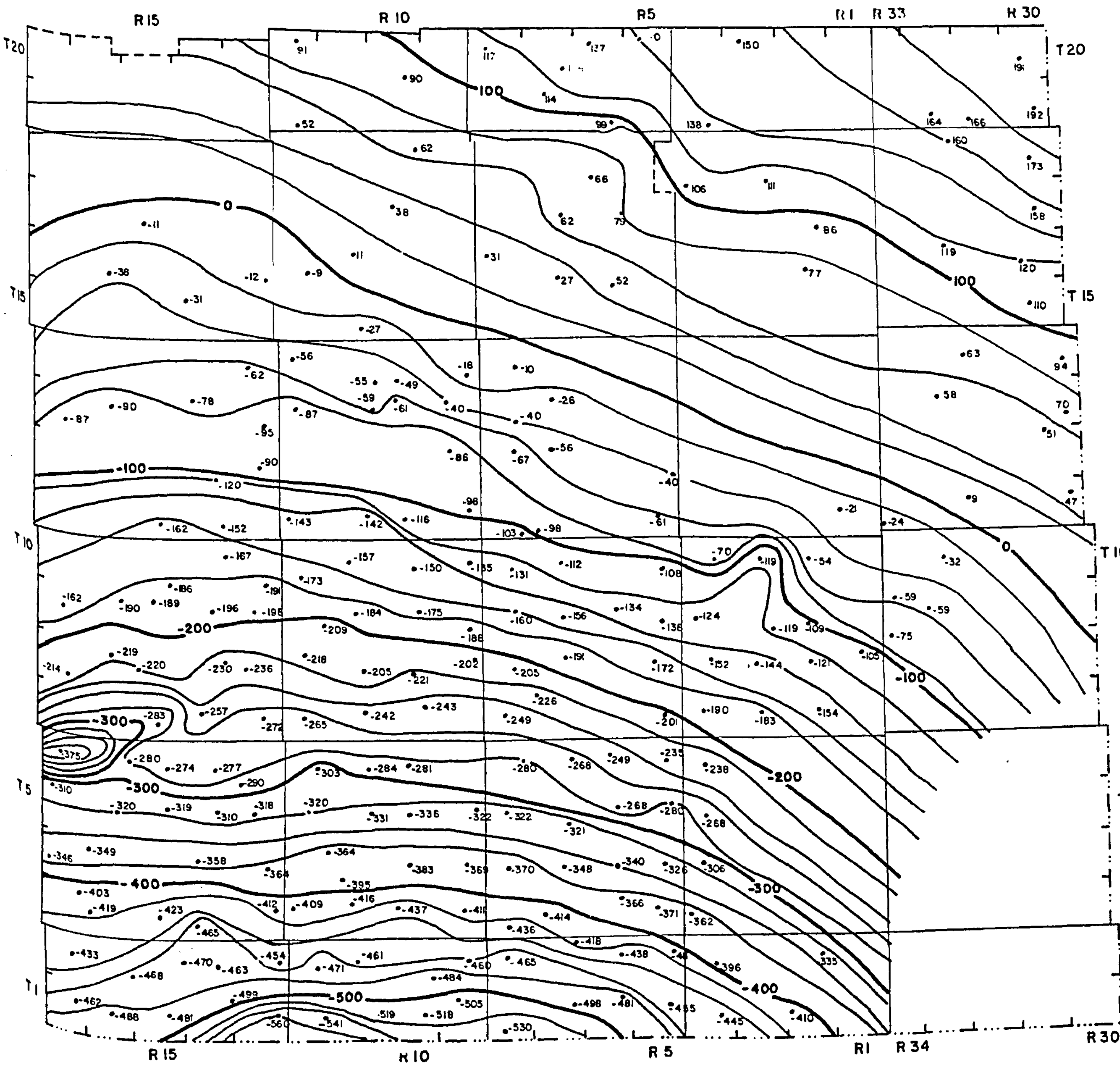


STRUCTURE CONTOURS
BASE OF LOWER COLORADO SUBGROUP

Figure - 19



10 5 0 10 20 30 40 50
Kilometres

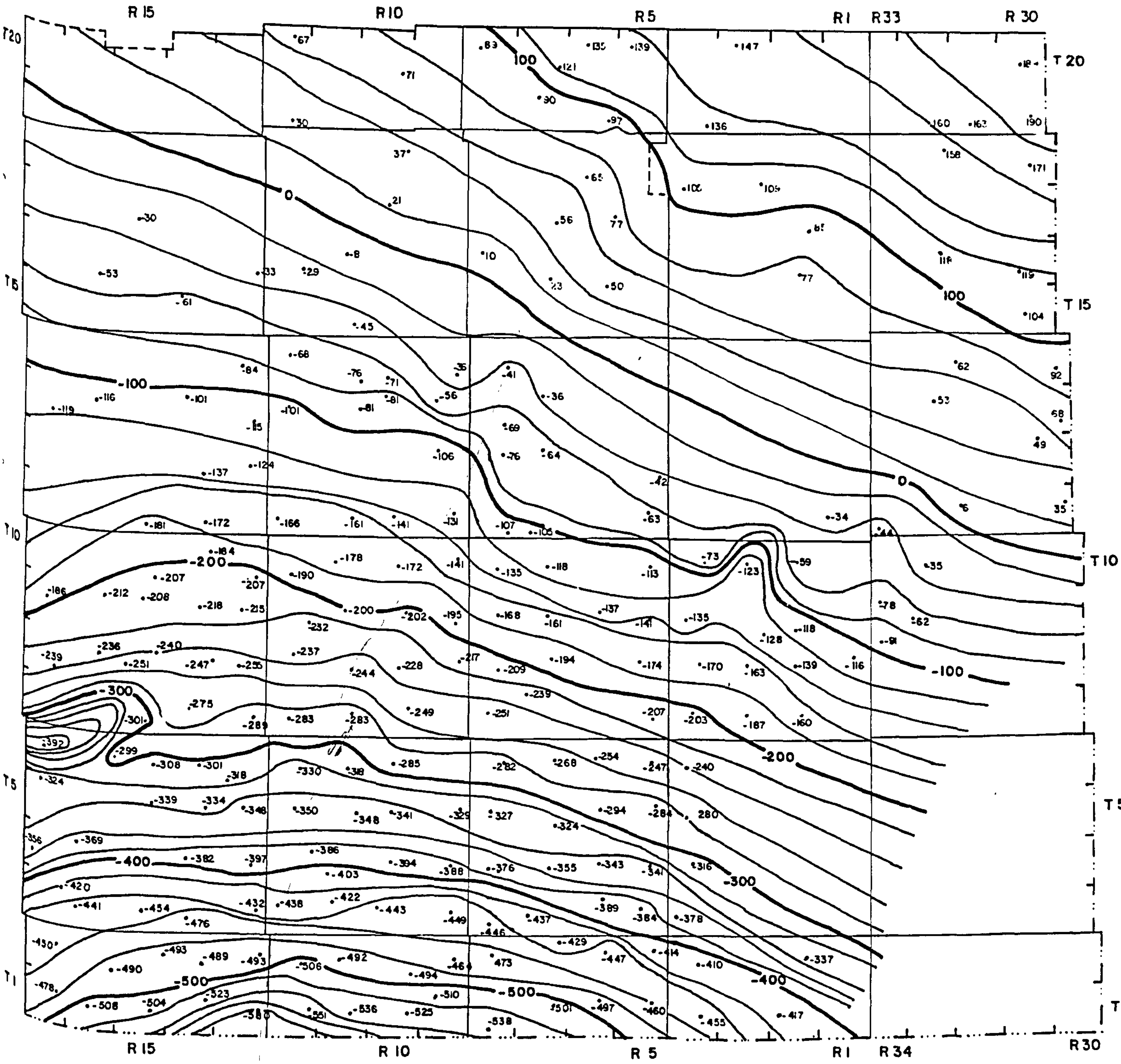
Contour interval - 20 metres

Structural Datum = Sea level

STRUCTURE CONTOURS

TOP OF VIKING FORMATION

Figure - 20



Contour Interval - 20 metres

Structural Datum = Sea Level

10 5 0 10 20 30 40 50

Kilometres

STRUCTURE CONTOURS

BASE OF VIKING FORMATION

Figure - 21

high isopachous values in sedimentary units overlying the position of the feature; (3) it may create a structural high, caused by draping over these thickened bodies of sediment; (4) it may create a structural depression which is present on an upper horizon but absent from the underling horizons.

The features described in (3) and (4) may only be determined to be the result of salt subsidence by examination of the complete sequence overlying the salt horizon. Determination of these features, therefore, is not within the scope of this study.

The southern edge of the Prarie evaporite underlies the western limit of the study area at Ranges 16 and 17 west of the 2nd Meridian, as far north as Township 13 (Fig. 16). The western edge of the Hummingbird trough underlies Ranges 16 and 17 W2 at Townships one and two. These features are not recognisable within the structure contours or isopach maps of the Lower Colorado Subgroup. This is because subsidence related to this feature occurred in pre-Cretaceous time, and its effects were obliterated by compensatory thickening of Early Mesozoic strata (Christopher, 1961). This feature is, therefore, not present on Lower Colorado or Mannville surfaces.

Two salt-solution features have been detected within the Lower Colorado of the study area by use of the structure contour and isopach maps. The largest of these is centered at Township 6, Range 17 W2. This is present within all the structure contour maps drawn on Lower Colorado surfaces. It covers an area of approximately four townships and has a relief of approximately 80 m, which remains constant throughout the Lower Colorado succession. The isopach maps show that there is no anomalous thickening of Lower Colorado sediments across this feature, thereby indicating that its formation post-dated these times.

This solution feature is situated at the western edge of the Hummingbird Trough. The linear trend of the feature parallels that of the northeast-southwest Rocanville-Torquay structure (linear no. 1, Fig. 16), and is situated in the area where this structure intersects the Hummingbird Trough. It appears, therefore, to be a northeasterly extension of the Hummingbird solution feature along this linear structure. According to Parker (1967) salt removal above regional lineaments is caused by movement along these structures. Fracturing of the overlying strata provides access of formation water to the salt beds thereby accelerating the removal of salt and the collapse of the overlying strata. A process similar to this appears to have taken place here.

The other salt solution feature in this area overlies the position of the Nelson River High. In southeastern Saskatchewan this gravity anomaly is curvilinear. It swings from a northeast bearing, north of the 51st Parallel of latitude to northwest, south of this Parallel (Fig. 16). The high enters the study area at Township 20 within Ranges 31 and 32 W1 and continues southeasterly to the Manitoba border in Township 11.

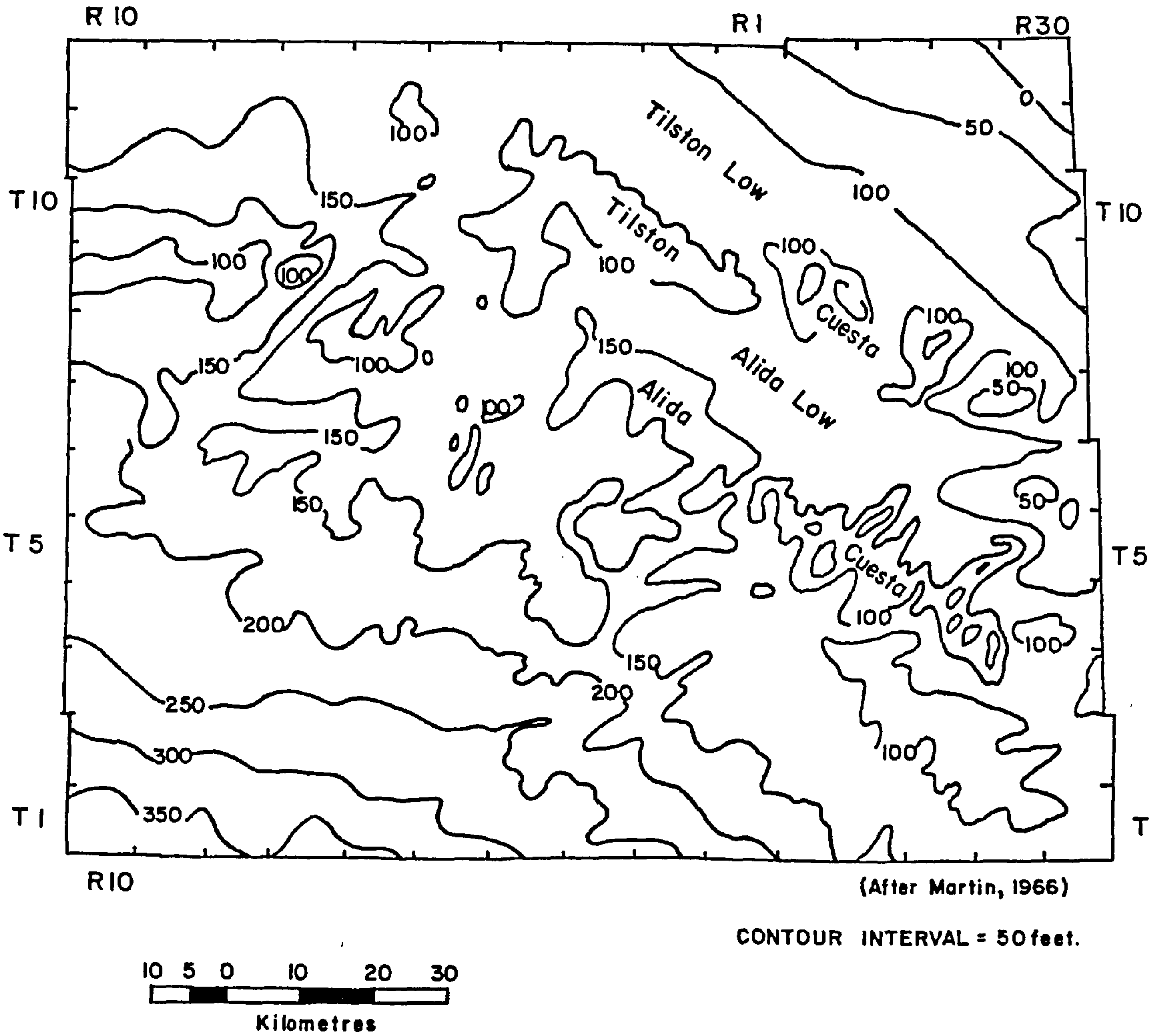
The structure contours on the Mannville Formation (Fig. 19), show that a north-south trending structural low with a relief of 20 m is centered on Township 19 Range 31 W1, but with a northerly extension at Township 20 Range 31 W1. This feature is not delineated by the contours on the Joli Fou, Viking or Big River Formations. The isopachs of the Joli Fou Formation show a corresponding thickening of

20 m, thereby indicating that the depression was formed at that time, probably in response to local salt solution.

The nature of the Nelson River High was investigated by Hajnal and McClure (1977) who constructed a seismic reflection profile across the anomaly in southeastern Saskatchewan at Township 27. This revealed the presence of a fault zone, extending downwards into the crystalline basement. This fault zone was active until the Late Cretaceous. They also detected two salt solution features in the central portion of the gravity anomaly in this area. Sawatsky (1968) has described a salt solution feature at Township 24, Range 1 W2 overlying the gravity anomaly. These support the conclusion that the solution formed depression seen within the study area at Township 19, Range 31 W1 was initiated by tectonic activity associated with the Nelson River High.

Sub-Mesozoic Unconformity

The Mississippian erosion surface in southeastern Saskatchewan forms a well developed cuesta landscape. The cuestas correspond to the subcrops at the erosion surface of the units that are most resistant to erosion. These formed well dissected uplands, separated by generally wide valleys (Von Osinski, 1970). The position of these cuestas in southeastern Saskatchewan is indicated by Figure 22, which is an isopach map of the red beds of the Triassic Lower Watrous Formation, after Martin (1966). The isopachous lows of this formation correspond to high elevations on the Mississippian erosion surface,



Isopach Map of Lower Watrous (Jurassic) Red Beds Southeastern Saskatchewan.

Figure - 22

which it directly overlies. The cuestas form elongated northwest-southeast trending ridges. These have blocky rectangular outlines separated by narrow valleys aligned perpendicular to strike.

The cuestas front dense carbonates of the Tilston limestones and the Alida limestone and evaporite units. The intervening valleys are in the Frobisher and Alida shales and sandstones. The subcrop of the Mississippian strata in this area, after Fuzesy (1960) is shown in Figure 23. The northern scarp of the Tilston extends from Township 6, Range 30 W1 to Township 12 Range 6 W2, and is shown in Figure 22.

These topographic forms influence the overlying strata in the following manner: (1) Their relief until buried by later deposition, forms isopachous highs and/or lows of the unit being deposited; (2) they cause folding of overlying strata by compaction of these strata over the topographic feature.

Within the study area two structural features in the region overlying the Tilston ridge and valley system are believed to be supratenuous, resulting from compaction over these pre-existing features.

A structural high of 30 m is present at the base of the Lower Colorado (Fig. 19), in Township 8 Range 33 W1. The structure is absent at the top of the Lower Colorado Subgroup. The Viking Formation is not present in this area, therefore the structure cannot be determined at this level; nonetheless the Lower Colorado thins by at least 47 m with respect to the surrounding wells. This indicates that this structural high was formed prior to, or during, deposition of the Lower Colorado sediments.

Along strike to the northwest of this structure, a depression on

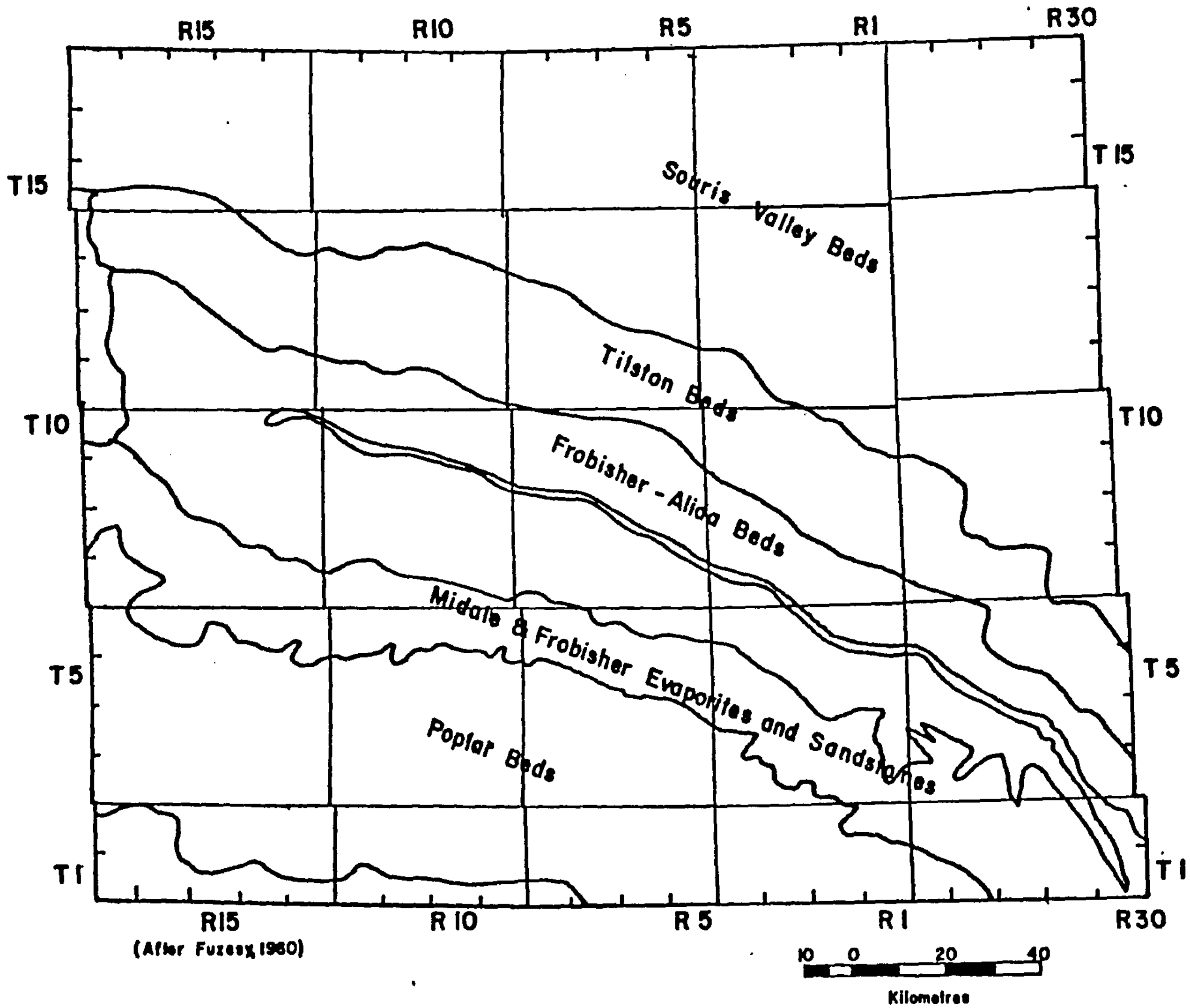


Figure -23 Mississippian Subcrop of Southeastern Saskatchewan the lower surface of the Lower Colorado Subgroup (Fig. 19) at Township 10 Range 3 W2 has a relief of approximately 60 m. At the base and top of the Viking this relief is 50 m and 30 m at the top of the Lower Colorado Subgroup (Fig. 18). The relief thus declines by almost 50 percent throughout the sequence. There is a combined thickening of the Joli Fou and Big River Formations of approximately 20 m. The thickening indicates that this is a syndepositional structure. The formation of the depression was continuous throughout Lower Colorado deposition, leading to limited thickening of the formations. It is also possible that the greater relief of the feature at the base of the Joli Fou and Viking Formations may be due to post-depositional compaction.

There are no structural anomalies within the Lower Colorado overlying the Alida cuesta (Fig. 22). This may be due to the southward thickening of the Jurassic System thereby masking the Mississippian topography and its influence upon the Cretaceous succession.

A structural cross-section of the Lower Colorado above a local high on the Mississippian erosion surface at Township 9 Range 6 W2 (Fig. 24) shows an anticline with a width of approximately 3.5 km and a relief of approximately 10 m (Fig. 25). The section shows that structurally the Lower Colorado sequence corresponds to the Mississippian topography. Neither the thickness or the distribution of the Lower Colorado Formations is affected by this structure. This indicates that the Lower Colorado structure was post-depositional in origin having been formed by compaction over the pre-existing Mississippian high.

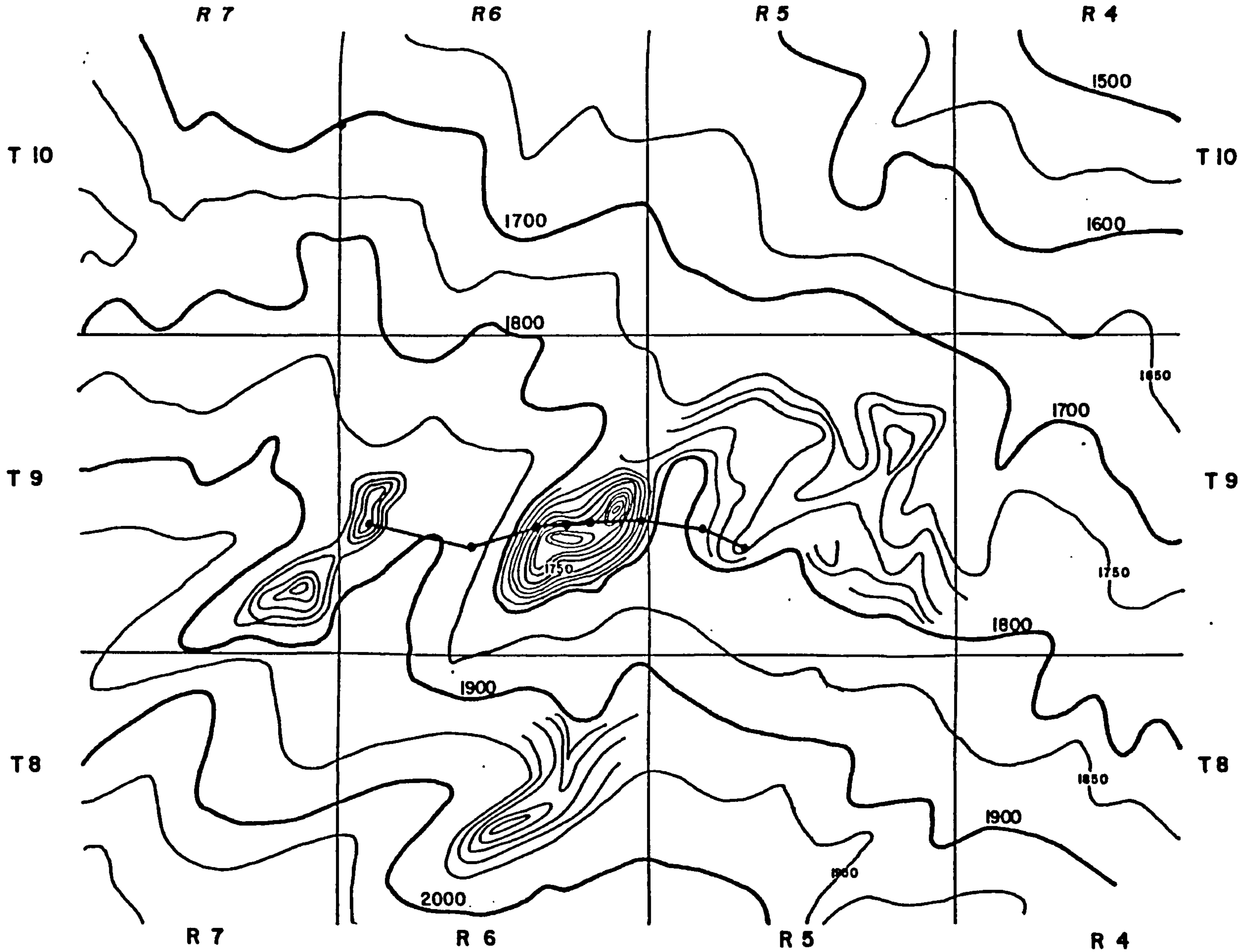


Figure - 24 Topographic High on Mississippian Erosion Surface (after Ledebur, 1976)
- Line of Structural Cross Section in figure 25 is shown. Contours Shown in feet.

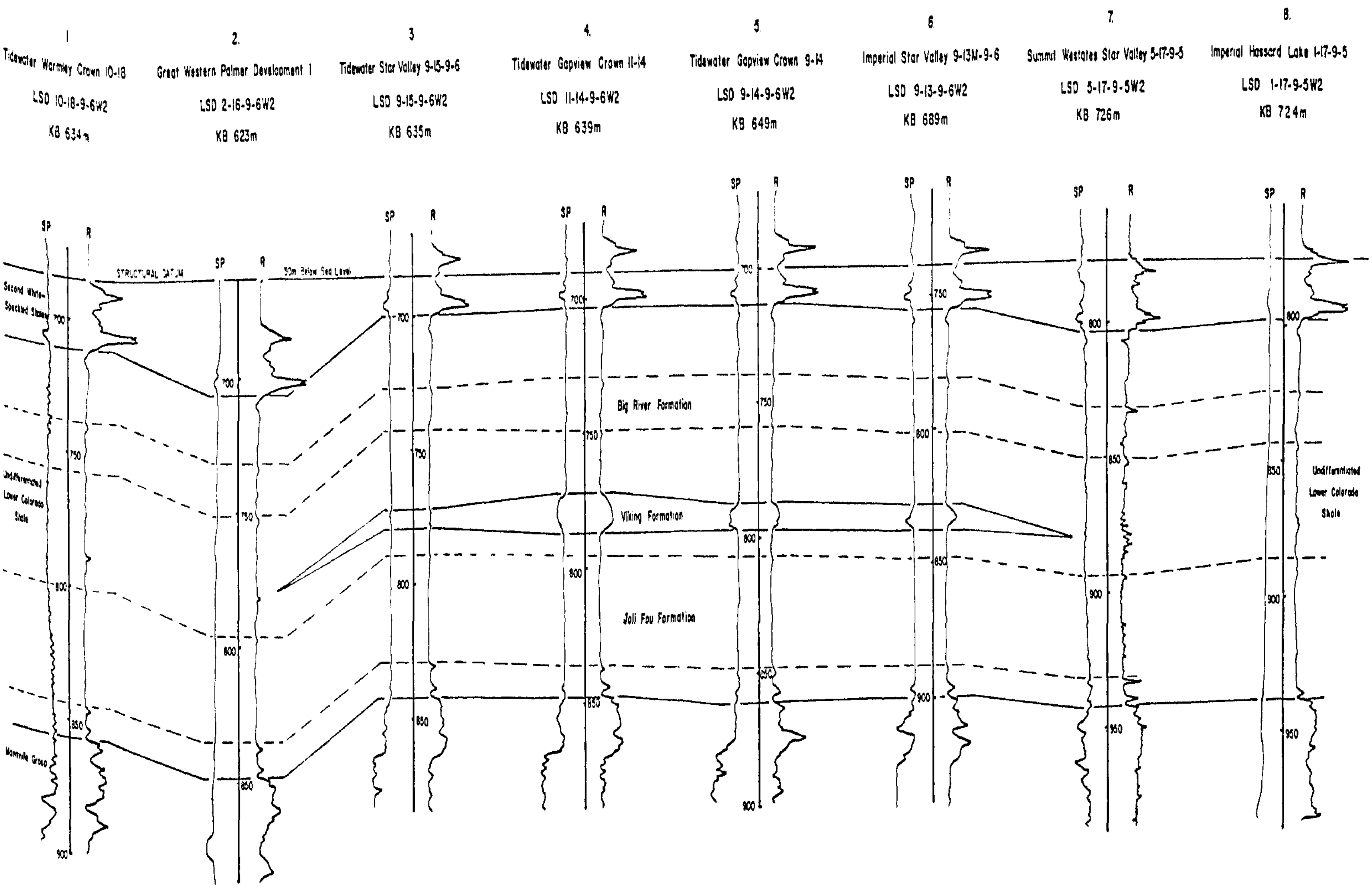


Figure - 25 WEST - EAST Structural Cross Section.

Basement Tectonics

A number of linear trends have been discerned within the area. The Rocanville-Torquay trend is a set of parallel northeast-southwest trending linears defined by Christopher (1961). A conjugate northwest-southeast set is also defined by (op. cit.) and Mollard (1957). Other localised trends are given by Kent (1973) and Kendall (1976).

The relationship of the Rocanville-Torquay trend to the salt solution feature in the southwestern part of the study area has been pointed out. The structure contours at the base of the Viking Formation (Fig. 22) show the possible influence of another linear structural feature. A north northeasterly trending synclinal flexure extends from Township 6, Range 10 W2 to Township 20, Range 5 W2 and coincides with the thickened eastern portion of the sheet sandstone (Fig. 10). This apparent linear may reflect a depression created by increased erosion of the Joli Fou Formation at this position rather than by tectonic movement. Moreover, there is no simple relationship between increased thickness of the Viking Formation and structural lows. This is seen for example, in Township 3, Range 9 W2 where there is an abrupt thickening of the Viking Formation without significant deflection of structure contours.

However, this flexure is also evident at the top of the Viking Formation (Fig 21), although subdued when compared to that at the base of the Formation, and it is reflected in a northeasterly deflection of the Big River isopachs in the northern part of the area from Township 11, Range 9 to Township 18, Range 6. Thus, persistence of this linear trend suggests that it may be structural.

The northern end of the north-south trending Nesson Anticline is situated approximately 30 km south of the study area. The axis of the anticline intersects the study area at Range 8 W2 but there are no corresponding structural features in this region.

Other Features

A number of isolated features do not appear to reflect any of the regional features discussed. A structural depression on the upper surface of the Viking Formation at Township 3 Range 14 W2 (Fig. 20) has a relief of approximately 30 m. The feature is not present on the structure contours above or below this level. The Viking Formation thins by approximately 10 m and the Big River Formation thickens by 20m. This feature appears to have been formed by erosion of the Viking Formation prior to the deposition of the Big River Formation.

A structural high on the Viking Formation at Township 12 Range 13 W2, has a relief of approximately 10 m. This corresponds to an increase in the thickness of the Viking Formation of 10 m and a decrease in the thickness of the Big River Formation of approximately 15 m. There is no corresponding structural anomaly on any of the other structural surfaces.

A structural depression on the Lower Colorado Subgroup at Township 4 Range 1 W2 (Fig. 18) is not present at the base of the Lower Colorado sequence. The Viking Sandstone is absent in this area.

The depression has a structural relief of approximately 60 m. There is a corresponding reduction of thickness of the Lower Colorado succession. This would seem to indicate that the depression was formed by erosion of Lower Colorado sediments at this position. It is also possible that this may be associated with underlying salt solution , as described in (4), p. 56.

LITHOLOGY

There are three major lithologies in the Joli Fou, Viking and Big River Formations. These are mudstones, siltstones and sandstones.

The mudstones form thick monotonous sequences in the Joli Fou and Big River Formations. They are dark grey, non-calcareous and usually quite shaly. They contain both fish-skeletal and plant debris. Sandy mudstones are developed within the Viking Formation. Units of interlaminated mudstone and sandstone are present in both the Viking and Big River Formations.

The siltstones occur generally as poorly laminated beds less than 5 m thick, and within graded sequences as intermediates between sandstone and mudstone. They are most conspicuous within mudstones of the Big River Formation. In the Viking Formation, they also occur as intervals containing thin, interlaminated sandstones.

The sandstones are the main constituents of the Viking Formation where they form thick units. They are generally fine- to very-fine grained, well sorted and quite mature. They are quartz-rich with feldspar and mica as minor constituents. They range from orthoquartzitic to subgreywacke in composition. Cementation is mainly chemical from silicate, carbonate or iron-rich solutions. Carbonaceous, organic material is abundant.

The sandstones are usually poor to moderately well laminated, with occasional cross-bedding. Bioturbation and burrowing are common. Induration is moderate to poor. Many sandstones contain a high proportion of silt and mud particles to form silty and muddy sandstone intervals. Within the Joli Fou and Big River Formations, the sandstones are thin and poorly developed.

The amounts of core examined from each Formation, and the relative proportions of the lithologies within them, are shown in Table II. The following lithologic descriptions are taken from the core and thin section data, presented in Appendices I and II respectively.

Lithologic Description

JOLI FOU FORMATION

This unit is present in two widely seperated cores taken in this area, one from Range 15 W2, Township 6 and the other from Range 1 W2, Township 14. Neither shows the contact of the Joli Fou with either the Viking Formation or the Mannville Group.

Mudstone

The Formation is chiefly composed of a uniform sequence of dark grey, non-calcareous, massive mudstones and horizontally laminated shales. The mudstones are occasionally streaked by millimetre to centimetre thick, sandy intercalations. The sands are fine-grained, quartzose and glauconitic at the Mobil Oil South Grassdale 32-10 well (LSD 10-32-6-15 W2). The sands have a fine, horizontal lamination. The mudstones at the Imperial Tidewater Wapella 9-33-14-1 well (LSD 9-33-14-1 W2), display scour marks in the form of small elongate, triangular flute moulds, on many surfaces. Bioturbation of the

Big River Formation

Total core recovery 23.6 m.

Core Constituents :	Amount of core (metres)	Volumetric Proportion
Mudstone	8.4	36%
Siltstone	8.2	35%
Sandstone & Mudstone	5.5	23%
Sandstone	1.5	6%

Viking Formation

Total core recovery 35.5 m.

Core Constituents :	Amount of core (metres)	Volumetric Proportion
Sandstone	24.7	70%
Sandstone & Mudstone	4.2	12%
Sandstone & Siltstone	2.2	6%
Sandy Mudstone	1.5	4%
Siltstone	1.1	3%
Silty Sandstone	1.1	3%
Carbonaceous Mudstone	0.4	1%
Muddy Sandstone	0.3	1%

Joli Fou Formation

Total core recovery 36.6 m.

Core Constituents :	Amount of core (metres)	Volumetric Proportion
Mudstone	34.5	94%
Sandstone	2.1	6%

Table II Main lithologies in cores of the Lower Colorado sequence within the study area.

mudstones is seen in parts of the section at the Mobil Oil South Grassdale 32-10 well (LSD 10-32-6-15 W2). A siderite concretionary layer 7 cm thick and a phosphate nodule are present at the Imperial Tidewater Wapella 9-33-14-1 well (LSD 09-33-14-1 W2).

Sandstone

At the Mobil Oil South Grassdale 32-10 well (LSD 10-32-6-15 W2), a fine-grained quartz sandstone 2.1 m in thickness is present. It is well laminated with low-angle, bi-directional cross-lamination. There is an increasing proportion of muddy laminae towards the top where it grades into mudstone.

Organic Constituents

Fish-skeletal debris is present at many levels within the mudstone of the Mobil Oil South Grassdale 32-10 well (LSD 10-32-6-15 W2). This is made up of black phosphatic fragments, within which well shaped spines are seen. They occur as scattered fragments or layers closely packed at discrete surfaces. These layers are not present in the mudstones of the Imperial Tidewater Wapella 9-33-14-1 well (LSD 9-33--14-1 W2), owing perhaps to a higher flow regime in the area of this well, as indicated by scour markings. This may have prevented the accumulation of skeletal debris.

VIKING FORMATION

The majority of the Viking cores came from the western part of the area. Five of the cores are from between Ranges 14 W2 and 16 W2 and one each is taken from Range 10 W2, 5 W2 and 31 W1. A total of five thin sections was obtained from the core four of which are from the western part of the area and one from Range 10 W2.

Sandstone

In general the Viking Sandstones are light grey, fine- to very fine-grained and quartzitic. They contain abundant carbonaceous, organic material and usually have been extensively bioturbated. Most have a poor horizontal lamination. Cross-bedding is present but not widespread.

Compositionally the sandstones show little variation. They are all quartz rich with very minor feldspar and mica elements. Clastic rock fragments are almost entirely lacking. Texturally they are fine- to very fine-grained, in some cases with a high proportion of silt-sized grains. The grains tend to be angular, but this is probably due to their small size. One interval with medium-grained sandstone was seen, this is present between 894.6 m and 897.6 m at the Shell Midale A-7-18 well (LSD 7-18-6-10 W2), and here the grain shapes are rounded. The grain/matrix ratio is generally high. Some sandstones show a high proportion of silt, these tend to have a high matrix content also, forming a subgreywacke. This is seen in the sections taken at 1189 and 1196 m of the Socony Central Del Rio West Ratcliffe 22-13 well (LSD 13-22-1-16 W2).

Some clastic rock fragments are seen within the medium-grained sandstone at the Shell Midale A-7-18 well (LSD 7-18-6-10 W2). These consist of a few, scattered fragments of fine-grained sand, embedded in an iron-rich cement.

The sandstone cementation mainly formed by authigenic growth of quartz is seen in the sections taken from the Oungre No. 1 well (LSD 7-1-2-14 W2), the Shell Midale A-7-18 well (LSD 7-18-6-10 W2) and the Socony Central Del Rio West Ratcliffe 22-13 well (LSD 13-22-1-16 W2) at 1191 m. The original outlines of the quartz grains are evident. These are surrounded by quartz growths, which have created idiomorphic outlines and sutured contacts between quartz grains, or show interfingering of quartz edges with organic or matrix material. This secondary quartz was probably precipitated from silica enriched, circulating pore waters, prior to consolidation of the sediments.

Chalcedonic silica also acts as a cementing agent, this is seen within the sections taken at 1189 m and 1196 m in the Socony Central Del Rio West Ratcliffe 22-13 well (LSD 13-22-1-16 W2). There is no reaction between the quartz grains and this silicic material, the original outlines of the quartz grains are preserved. Many grains are floating in this material. It would appear then, to be a primary constituent of the sandstone. Calcite and siderite are primary cements within the medium-grained sandstone seen in the Shell Midale A-7-18 well (LSD 7-18-6-10 W2).

The matrix of the subgreywackes in the Socony Central Del Rio West Ratcliffe 22-13 well (LSD 13-2-1-16 W2), at 1189 m and 1196 m is highly silicic with subordinate clay constituents, such as chlorite and sericite. Organic material is abundant within most of the sandstones. Zircon is a widespread heavy mineral accessory.

In general, the sandstones are moderate to poorly indurated. Induration tends to increase as the percentage of silt- and mud-sized particles increases within the sandstone. Generally the sands tend to be flaggy at the base and increase in induration as they grade into silty or muddy lithologies. This relationship is particularly well seen in the Imperial Canadian Superior Martin well (LSD 1-3-12-31 W1). Well indurated sections are also produced by siderite or calcite cement. Bands of siderite and limonite up to 7 cm thick occur in the Socony Central Del Rio West Ratcliffe 22-13 well (LSD 13-22-1-16 W2), at 1188.9 m (Plate 1a). Similar concretionary bands are present in the sandstones of the Richfield-B-A-Williston Sandercock 10-28 well (LSD 10-28-9-15 W2), at 765.5 l m, and the Imperial Stillman 1-8-4-5 well (LSD 1-8-4-5 W2) at 928.7 m.

Generally the sandstone sequences show no noticeable coarsening- or fining-upward characteristics. Exceptions to this are seen in; the Shell Midale A-7-18 well (LSD 7-18-6-10 W2), where the sandstone shows a gradual coarsening upwards of grain size; and the Imperial Canadian Superior Martin well (LSD 1-3-12-31 W1), where the Viking sand grades upwards into Big River mudstones.

Many of the sandstones have poor to moderate horizontal lamination. Quite often all internal organisation has been disrupted by extensive bioturbation. This is particularly visible in the silty sandstone between 1023 and 102.1 m of the Socony Central Del Rio Tribune 31-12 well (LSD 12-31- 3-14 W2). Bioturbation and burrowing are ubiquitous and sand-and mud-filled burrows up, to 6 mm in diameter, are common. These features are shown in Plate 1b.

Approximately 20 percent of the Viking sandstones contain cross-bedding or allied structures. These are cross-bedding with low-angle, planar foresets, seen in the Richfield-B-A-Williston Sandercock 10-28 well (LSD 10-28-9-15 W2), and at the Imperial Stillman 1-8-4-5 well (LSD 1-8-4-5 W2), where undulating lamination is also present. In the Oungre No. 1 well (LSD 7-1-2-14 W2), undulating lamination, low angle bi-directional cross lamination and trough cross lamination are present as well as, wavy-bedded sandstone and isolated, starved ripples (Reineck, 1968). These features are shown in Plates 2a, 2b and 3a.

No distinctive sequential order can be ascertained from the occurrence of these structures. At the Imperial Stillman 1-8-4-5 well (LSD 1-8-4-5 W2), the horizontal lamination developes upwards into an undulating lamination, which is succeeded by low-angle cross-lamination . In the Richfield B-A Williston Sandercock 10-28 well (LSD 10-28-9-15 W2), the cross-bedded sandstone unit, 0.2 m thick, is preceeded and terminated by horizontally laminated siltstones. A sequential order is not seen in the structures of the Oungre 1 well (LSD 7-1-2-14 W2), due in part to the fragmentary nature of this core. In no core is a development from massive sandstones into horizontally laminated or cross bedded sandstone seen.

An interval consisting of repeatedly graded sandstone-siltstone-mudstone units, 2.1 m in thickness is seen at the Socony Central Del Rio West Ratcliffe 22-13 well (LSD 13-22-1-16 W2). The graded units are between 2 cm and 4 cm in thickness. The sandstone, which is well laminated, light grey and fine-grained grades upwards into a very fine-grained sandstone succeeded by an olive grey siltstone (Plate 3b). This is succeeded by a millimetre to centimetre thick dark grey mudstone. The contact between this mudstone and the fine-grained sand at the base of the succeeding sequence is sharp and irregular. In some cases, grading is discontinuous, e.g., a rounded sandstone pebble approximately 4 mm in diameter occurs at the top of a graded interval within the mudstone, giving a deflection of the laminae (Plate 3b).

The sandstone is similar in composition to those previously described in this Formation. It consists of quartz grains, set in a silicic matrix with subordinate clays and abundant carbonaceous material. The bed becomes dominantly silty in places, forming a siltstone layer 0.1 m in thickness. This contains irregular layers and lenses of very fine-grained, light grey sandstones. The siltstones and intercalated sandstones are in sharp contact ; sand injection structures are present at the contacts.

In the Mobil CDR Flat Lake 12-30-1-15 well (LSD 12-30-1-15 W2), there is a 3 m thick closely interlaminated, fine-grained quartz sandstone and dark grey mudstone. The sand and mud are in sharp contact frequently with minor loading features at the sand-mud interfaces. The sandy and muddy units occasionally thicken, sometimes up to 12 cm. In these cases the sand is massive and poorly indurated.

A muddy sandstone, 0.3 m thick, is present at the Imperial Canadian Superior Martin well (LSD 1-3-12-31 W1). It consists of a light olive grey sandstone with a high mud content, in which all primary lamination has been obliterated, owing to extensive bioturbation. It contains many mud-filled burrows, This bed occurs at the top of the Viking Formation and is gradational to the Big River Formation.

Siltstone

Two siltstones, one 0.6 m and the other 0.5 m thick, are present within the Viking Sandstone in the Richfield-B-A-Williston Sandercock 10-28 well (LSD 10-28-9-15 W2). This siltstone is medium grey with poorly developed horizontal lamination. It also contains well preserved plant remains. Siltstone also occurs within the graded sand-silt-mud intervals, previously described from the Socony Central Del Rio West Ratcliffe 22-13 well (LSD 13-22-1-16 W2).

Mudstone

A sandy mudstone, 1.5 m in thickness at the Imperial Stillman 1-8-4-5 well (LSD 1-8-4-5 W2), occurs at the top of the Viking Formation and is transitional to Big River mudstones. It consists of a light grey mudstone containing thin irregular concentrations of sand. Abundant carbonaceous material is present. Mudstone is present within the sandstone of the Oungre No. 1 well (LSD 7-1-2-14 W2), where starved ripples and wavy bedding are seen.

A thin band of black, brittle and vitreous, carbonaceous mudstone occurs at the Socony Central Del Rio West Ratcliffe well (LSD 13-22-1-16 W2), at 11954.3 m. This is only a few centimetres in thickness and is sharply bounded by sandstone at its upper and lower contacts. A similar layer of carbonaceous mudstone occurs at 926.1 m in the Imperial Stillman 1-8-4-5 well (LSD 1-8-4-5 W2).

Other Features

A single bentonite clay layer 12 cm thick is recorded. This is seen in the Socony Central Del Rio West Ratcliffe 22-13 well (LSD 13-22-1-16 W2), at 1196.6 m. Burrows within the very fine-grained sandstone at the Imperial Stillman 1-8-4-5 well (LSD 1-8-4-5 W2), are infilled with pyrites and chalcopyrites (Plate 4b). These are epigenetic mineral segregations, having been introduced into the more permeable burrow-fill post-depositionally by a migrating solution.

The source of the copper solution was probably from underlying or overlying formations. The origin of the copper may have been from continental metalliferous sources or it may have been leached from volcanic material deposited within these formations. The precipitation of sulphides indicates a reducing environment. It seems, therefore, that at some stage after deposition, changing Eh-pH relations within the Viking Formation created this environment, allowing precipitation of these minerals (Samama, 1976).

Small, black, rounded phosphate nodules are also present.

Organic Constituents

Bioturbation and burrow forms are abundant within all lithologies of the Formation. Teichichnus is identified within muddy and silty sandstones of the Socony Central Del Rio West Ratcliffe 22-13 well (LSD 13-22-1-16 W2) and are shown in Plate 1b.

Plant debris is widespread and abundant in all lithologies of the Formation. It forms large irregular patches of soft, black carbonaceous material. This is shown in Plate 5a, which is taken from the Socony Central Del Rio Tribune 31-12 well (LSD 12-31-3-14 W2).

Two occurrences of well preserved plant remains were noted. One, from a graded siltstone-sandstone at the Socony Central Del Rio West Ratcliffe 22-13 well (LSD 13-22-1-16 W2), is an intact Angiosperm leaf (Plate 5b). This has been tentatively identified as Ficus ovatofoliata Bell (1965). The other is seen within a siltstone at Richfield B-A Williston Sandercock 10-28 (LSD 10-28-9-15 W2), and consists of a leaf-bearing Pteridophyte stem. It is tentatively identified as Klukia canadensis Bell (1956) and is shown in Plate 6a.

Featureless, black-brown organic material is an abundant constituent of many of the sandstones. This forms thin irregular, horizontal laminae or shapeless masses between grains or in the matrix. This material forms up to 20 percent of the rock in the sections taken from the Oungre No. 1 well (LSD 7-1-2-14 W2). Scattered, black, phosphatic, fish-skeletal debris is seen within the sandstone at the Imperial Canadian Superior Martin well (LSD 1-3-12-31 W1).

BIG RIVER FORMATION

Big River cores are taken from six locations within the area : Two from Range 16 W2, at Townships 1 and 6, one from Range 15 W2, Township 9, two from Range 5 W2, Townships 1 and 4 and one from Range 31 W1, Township 12.

The amount of siltstone and sandstone as shown in table II, is proportionally high, presumably because these cores were taken with these siltstones and sandstones as their targets.

Mudstones

These form thick monotonous sequences. In the Imperial Stillman 1-8-4-5 well (LSD 1-8-4-5 W2), the mudstone is typically dark grey with an even horizontal planar lamination, becoming quite shaly in parts (Plate 6b). It contains millimetre-thick streaks of very fine-grained sandstone. This sand is glauconitic in the Imperial Canadian Superior Martin well (LSD 1-3-12-31 W1). The mudstone is non-calcareous, but contains a 3 cm thick calcite segregation at 924.4 m in the Imperial Stillman 1-8-4-5 well (LSD 1-8-4-5 W2).

Siltstone

This forms units between 0.3 m in thickness, as is seen in the Socony Central Del Rio West Ratcliffe 22-13 well (LSD 13-22-1-16 W2, and 4.9 m in thickness, in the Richfield B-A Williston Sandercock 10-28 well (LSD 10-28-9-15 W2). They are non-calcareous, medium grey in colour and usually massive or poorly laminated. They occasionally exhibit a well developed planar horizontal lamination. Repeated siltstones, grading upwards into thin layers of mudstone, are seen at the Socony Central Del Rio West Ratcliffe 22-13 well (LSD 13-22-1-16 W2). In the Imperial Federated Coop Palmer North Portal 02-29 well (LSD 12-29-1-5 W2), the siltstone contains a few millimetre-thick discontinuous sand layers. This unit, which is 1.2 m thick, has been subjected to bioturbation and contains many sand-filled burrows.

Sandstone

A single sandstone unit, 1.5 m in thickness is seen in the Imperial Federated Coop Palmer North Portal 12-29 well (LSD 12-29-1-5 W2). This consists of a light grey, very fine-grained quartz sandstone. It contains very minor feldspars and micas, with abundant organic material. It has a quartzose texture; cementation is due to authigenic growth of quartz, which creates sutured contacts between grains.

It has been extensively bioturbated and lacks internal organisation. Many sand-filled burrows are present. It is well indurated at the base, becoming poorly indurated upwards.

Interlaminated sandstones and mudstones form beds up to 4 m in thickness near the base of the Formation in the Socony Central Del Rio Grassdale 1 well (LSD 6-2-7-16 W2). The sandstones occur mainly as millimetre-thick laminae interleaved with dark grey mudstones. The contact between them is sharp with minor loading and sand injection structures. The sandstones occasionally form massive beds up to 4 cm thick. Detached, ptygmatic folding of sand-mud laminae is seen within a dominantly sandy unit (Plate 7a).

The sandstone is light grey, fine-grained and highly quartzose with few feldspars and micas. Argillaceous rock fragments are absent. Cement is mainly authigenic quartz derived from primary silica solution or microcrystalline chert. Bands of calcite and siderite cementation are present, indicating that local concentrations of calcite and ferrous iron were occasionally high during deposition.

Other Features

Two thin layers of light grey bentonite clay are seen; a 12 cm thick band in the Richfield B-A Williston Sandercock 10-28 (LSD 10-28-9-15 W2), containing small crystals of biotite; the other, 3 cm thick, in the Imperial Stillman 1-8-4-5 well (LSD 1-8-4-5 W2).

Organic Components

The mudstones seen in the Imperial Canadian Superior Martin well (LSD 1-3-12-31 W1), contain phosphatic fish-skeletal debris, both as scattered fragments and in packed discrete layers (Plate 7b). Well preserved teeth are present phosphatic debris is much more sparse within the mudstones and silltstones in the Imperial Stillman 1-8-4-5 well (LSD 1-8-4-5 W2).

Black carbonaceous fragments are quite abundant within the sandstone, but are only occasionally seen within the siltstone. A single, small, phosphatic cone was seen in sandy mudstone at the Socony Central Del Rio Grassdale No. 1 well (LSD 6-2-7-16 W2). This is probably fish-skeletal in origin.

East-West Lithological Variation Within the Viking

The total amount of core taken from the thick western development of the Viking Sandstone within the study area is 26.5 m. The total amount taken from the thin eastern Viking in this area is 9 m. It is clear that the meager eastern data do not permit firm conclusions on lithological differences between these two areas.

The gross lithological characteristics of the rocks are quite similar. Sandstone makes up 66 percent of the western cores and 80 percent of the eastern cores. The remainder in each consists mainly of similar muddy and silty sand types. The sandstone features are similar in both areas. Horizontal lamination and low-angle, planar cross-bedding are seen in both, e.g., in the Richfield B-A Williston Sandercock 10-28 well (LSD 10-28-9-15 W2) in the west and in the Imperial Stillman 1-8-4-5 well (LSD 1-8-4-5 W2) in the east. Both areas reveal a high percentage of carbonaceous material and fish-skeletal debris and a high degree of bioturbation. Properties, such as induration and colour of the lithologies, do not differ greatly.

A medium-grained sandstone with a calcareous cement is present in the Shell Midale A-7-18 well (LSD 7-18-6-10 W2). This well is in the eastern area of thin sandstone. Neither of these features is present in the cores taken from the western area. Also in this location the grain size of the sandstone increases upwards, there is no corresponding gradation either upwards or downwards in the western arèa.

Wavy-bedded sandstone and starved ripples, which are present in the Oungre No. 1 well (LSD 7-1-2-14 W2), in the western sandstone region, are not seen in cores from the eastern area. The small-scale graded units in the Socony Central Del Rio West Ratcliffe 22-13 well (LSD 13-22-1-16 W2), are not in the eastern area.

Lithological Comparison with Adjacent Areas

One core was examined from a location outside the study area; this was from the Imperial Esk 7-14-33-20 well (LSD 7-14-33-20 W2), for description see Appendix I(a). This core incorporated the complete Viking sequence, including its contact with the Joli Fou and Big River Formations.

The Viking sequence here is 7.3 m thick, of which 5.5 m consist of sandstone. These sandstones are fine- to very-fine grained, quartz-rich with very minor feldspar and mica content. Featureless, brown-black organic material is abundant. Cementation is by primary silica, calcite and siderite. Much of the sandstone is extensively bioturbated; Teichichnus is present. Thin horizontal, muddy and silty laminations occur within sandy units. Thin, cross-laminated, fine-grained sandstone occurs within silty intervals. A mudstone and a sandy siltstone layer, 0.9 m and 0.8 m in thickness respectively, are present. The base of the Viking Sandstone consists of a glauconitic, muddy sandstone. Thin bentonite and siderite layers are also present.

The Joli Fou and Big River Formations consist of thick, monotonous dark grey mudstones, similar to those in the study area.

They are non-calcareous, contain fish-skeletal debris, and some irregular lenses of very fine-grained quartz sandstone, usually only a few millimetres in thickness. Silty mudstones, bentonite layers and siderite zones also occur. Generally the lithological features seen here vary little from those within the study area.

The main cores from the Lower Colorado Subgroup within the area of the eastern Viking depositional system in Saskatchewan, has been described by Simpson (in press b). These descriptions have been reviewed by the author in order to make a comparison with the lithologies of the study area.

The proportion of the lithologies within these cores, excluding those of the study area, is tabulated in Table III. When compared with Table II, for the study area, it is seen that the lithological proportions of the Joli Fou and Viking Formations of both areas are similar. The dissimilarity of the proportions of Big River lithologies shows the imbalance of the sample within the study area as previously noted.

This correlation, particularly of the Viking Formation, is significant in that it shows that the sample obtained within the study area is representative for the depositional system as a whole.

The contact between the Joli Fou and the Viking Formations is present in some of the cores described by Simpson (in press b). This contact, between sandstone and mudstone, is always sharp. There are no coarse lithologies, such as conglomeratic or pebbly sandstone, seen at the base of the Formation.

Five of the thin sections taken from the Viking Formation adjacent to the study area by Simpson (in press b) were examined by

Big River Formation

Total core recovery 199.5 m.

Core constituents :	Amount of core (metres)	Volumetric Proportion
Mudstone	170.0	85%
Mudstone and Siltstone	11.6	6%
Mudstone and Sandstone	6.0	3%
Sandstone	5.5	3%
Siltstone	4.6	2%
Siltstone and Sandstone	1.5	0.7%
Bentonite	0.3	0.1%

Viking Formation

Total core recovery 186.7 m.

Core constituents :	Amount of core (metres)	Volumetric Proportion
Sandstone	140.7	75%
Sandstone and Mudstone	19.5	11%
Mudstone and Siltstone	12.5	7%
Sandstone and Siltstone	7.6	4%
Sandy Siltstone	4.0	2%
Mudstone	2.4	1%

Joli Fou Formation

Total core recovery 122.8 m.

Core constituents :	Amount of core (metres)	Volumetric Proportion
Mudstone	108.3	88%
Sandstone	9.6	8%
Sandstone and Mudstone	4.9	4%

Table III Main lithologies in cores of the eastern Viking depositional system, Saskatchewan.

the present author. One each was taken from Ranges 20 W2, 10 W2, 5 W2, and three from 8 W2. All were from between Townships 30 to 35. Appendix II(a) gives a complete list of corresponding well locations.

All the sections are of sandstones. These show little texural or compositional variation. They are medium- to fine-grained with one section containing some coarse sand grains. The coarse and medium grains are well rounded, the smaller grains subangular to subrounded. They are quartz-rich with feldspar and mica as very minor constituents, clastic rock fragments are absent. Organic material is generally lacking. All of the sandstones have a well developed primary calcite or siderite cement, none have quartz cementation. These sections are compositionally, texturally, and in their cementation, similar to the Viking sandstones in the study area as seen in the Shell Midale A-7-18 well (LSD 7-18-6-10 W2).

One section taken from a sandstone within the Joli Fou Formation at Township 32, Range 8 W2 reveals a mature, very fine-grained sandstone with calcite cement, similar to those previously described from the Viking Formation.

Lithological Interpretation

The lithological analysis of the formations in this area must of necessity be limited. This is due to such factors as the small amount and poor distribution of the core recovery and the lack of complete or continuous core through the Viking Formation. This does not allow a meaningful comparison to be drawn between different parts of the area, nor a lithological or petrographic correlation to be made. The material does, however, lend itself to a broad study of the sediments, particularly with respect to their origin and depositional environment.

The Viking Formation

The sands within this formation show a high degree of maturity. There is a low textural variability between samples. They are generally fine-grained, the coarsest material present is medium-grained and this shows good rounding. The largest clasts are locally derived phosphate pebbles. Argillaceous rock fragments are absent and unstable minerals, such as micas and feldspars, are relatively rare. The fragments of soft, fine-grained iron-cemented sandstone seen in the medium-grained sandstones, are almost certainly locally derived. Cementation is by authigenic quartz, chert, siderite and calcite. Detrital cementation occurs only where proximal to shale transitions.

The depositional setting for such a sandstone is that of a nearshore marine or shallow marine shelf environment. The sediments were extensively sorted and reworked prior to deposition, possiibly in a shoreline complex which the material had passed through. Thus unstable minerals and rock fragments are absent, as is coarse material other than that which is locally derived. Local constituents, such as detrital skeletal debris and phosphate pebbles, are present. Cementation is mainly chemical. If these sediments were derived from the stable cratonic shield to the east and northeast, the compositional maturity of the sands would be due in part to the nature of its provenance.

The sand units in general appear to show no pronounced vertical size trend. Both fining-upwards and coarsening-upwards transitions are seen. Generally the sandy units show a medium to poor horizontal lamination. This, and low-angle cross-lamination suggest a shallow water, high energy environment (Reineck, 1967; Hamblin et al., 1979). The various sand-silt-mud associations within the formation suggest a depositional setting in which intermittent turbulence was common. Sands representing potentially high-energy conditions alternate with muds representing potentially low-energy conditions. The type of alternation is variable throughout the succession.

Bi-directional trough cross-laminae, ripple and wavy bedding, indicate the operation of currents. These may have been tidal (Reineck, 1967), or wave-generated (Raaf et al., 1977).

Both coarsely and finely interlaminated sand-mud and sand-silt sequences are interpreted as tidal bedding. The variety of the sediments reflects the variability of currents due to such factors as flood and ebb tides, sand lamellae being deposited during flood tide, and mud lamellae at ebb tide. This oscillation is also indicated by wavy bedding and starved ripples, the genesis of which is related tidal rhythm. The preferred environment for these structures is the subtidal and intertidal zone (Reineck and Wunderlich, 1968). According to Reineck (1967), the preferred depth for deposition of a substantial mud fraction in this setting is greater than 20 m owing to the strength of currents at shallower depths.

The development of the small-scale sand-silt-mud graded units within the Formation may be related to tidal intermittent currents. It is probable, however, that these are storm-generated layers formed by material falling out of suspensions generated by storms, thus forming graded units. This material is laid down on an erosional base with associated high-energy characteristics. The grading is also seen to be discontinuous in places. This is consistent with the storm-generated layers described by Simpson (1975), throughout the Colorado Group in Saskatchewan.

Extensive bioturbation is present throughout the sequence. The incidence of bioturbate structures is greatly reduced where sedimentation rates are high. This indicates that deposition throughout this sequence was either slow or intermittent. The only lithology present without bioturbate structures is the fine- to medium-grained horizontally laminated sandstone present in the Shell Midale A-7-18 well (LSD 7-18-6-10 W2). This is the coarsest sandstone seen within the Formation and appears to have been rapidly deposited in high-energy conditions. According to Reineck (1967), intensive bioturbation in this type of setting is present in water depths up to and over 50 m.

Carbonaceous, organic matter is widespread and abundant within this Formation and may indicate the influence of a fluvio-deltaic system, which could transport great quantities of this material into the marine environment. The deposition of this material within the Viking appears to have been through fall-out from suspension. This is indicated by the presence of well preserved plant remains in the siltstone sequences. The fact that these are relatively intact and occur parallel to the bedding plane shows that they were deposited during a low-energy, quiescent phase. Their presence, however, does not necessarily indicate proximity to a shoreline, since plant fragments are thought to be able to travel considerable distances from the shoreline without appreciable deterioration. The wide distribution of this material throughout the sandstone may have been brought about by mixing of the unconsolidated sand and organic material through bioturbation.

It is also possible that much of the plant material in this environment may have been introduced by storm-generated turbulence. These events would have removed great volumes of organic material from a deltaic environment and transported it into the shallow-water marine environment. The sharply bounded layers of carbonaceous mudstone within the sequence may be storm layers, formed by organic material that rapidly fell out of suspension following rapid storm-induced transportation.

The Joli Fou-Big River Formations

These Formations are dominated by thick monotonous sequences of dark grey, non-calcareous mudstones, containing much fish-skeletal debris and widespread bioturbation. They represent a deeper marine environment than that in which the Viking sediments were deposited. These muds include intermittent, very fine-grained glauconitic sandy and silty layers. These sands are texturally and compositionally highly mature. Upwards fining is seen within a sand unit in the Joli Fou and within a siltstone unit in the Big River Formation.

Reineck and Singh (1971) have discussed the genesis of sand and silt layers in shelf mudstones. They found that these layers are characteristically sharp-based, horizontally laminated and grade upwards into mudstones. They are found in waters up to 40 m in depth and up to 45 km from shore. They believe that these are formed by sand that has been whirled up by storm-generated wave turbulence and carried out into open sea in suspension by high wave energy. The lessening of this wave energy allowed suspension clouds to settle, forming parallel, evenly laminated layers. This origin may account for the widespread distribution and persistence of these layers within the study area.

The Viking sands were further affected by intermittent bottom currents, causing weak cross-lamination in some layers. These currents have also eroded scour structures in some mudstones and deposited irregular, millimeter thick sand and silt layers within many of the mudstone sequences.

The presence of these sands and their current-formed structures, in association with the bioturbate structures found within the various lithologies, suggest that these formations represent a shelf environment of moderate rather than a great depth. The gradation from Viking to Big River sediments consists of thin beds of intermediate sandy and muddy lithologies representing what appears to be a gradual transgression.

EXTERNAL RELATIONS - VIKING FORMATION

There is a disconformity present at the base of the Viking Sandstone. This is indicated by the clearly defined erosional relationship between the Viking and Joli Fou Formations; (c.f. Figs. 4 and 10). The thicknesses of the two formations are inversely proportional in that an increase in the Viking Formation corresponds to a decrease in the Joli Fou and conversely.

This is demonstrated most notably in the central region of maximum Viking thickness that extends north-northeasterly from Township 1, Range 12 W2 to Township 20, Range 6 W2

A more specific example of this relationship is shown by the two areas of increased thickness of the Viking Formation centered in Township 3, Range 9 W2 and in Township 2, Range 13 W2. These are separated by an area of thinning amounting to approximately 35 m. These thick sands correspond to equivalent thinnings of the Joli Fou Formation, and the area of thinning to a Joli Fou thickening of up to 30 m.

Further evidence of this disconformity is presented by the abrupt truncation of many of the upper Joli Fou silty and sandy markers where the Viking Formation thickens. The continuous nature of these silty and sandy horizons over long distances is demonstrated by Figure 5, a northeast-southwest stratigraphic section, and Figure 13, an east-west stratigraphic section. These markers remain parallel to each other and to the lower surface of the Joli Fou Formation.

Abrupt truncation of these markers is seen in the north-south stratigraphic section of Figure 7, between the White Rose Devon Palmer et al Tableland 8 well (LSD 8-22-2-9 W2) and the Homestead Siboney Hitchcock 13-22 well (LSD 13-22-3-9 W2). The truncation is caused by an increase in thickness of the Viking Sandstone between these two wells. The marker bed reappears to the north at the Shell North Blewitt A3-28 well (LSD 3-28-5-9 W2), where the Viking Formation is reduced in thickness. Further truncations of marker horizons are seen in the northern part of this section, particularly at the B A Husky Philips Bemersyde 1 well (LSD 3-11-13-8 W2), and the Imperial Kegworth 3-14-14-8 well (LSD 3-14-14-8 W2).

Truncation of marker beds in the Joli Fou Formation are also seen in the much more local stratigraphic section of Figure 8 particularly between the Benedum Trees Dome Halbrite 5-9-7-11 well (LSD 5-9-7-11 W2) and the Cannso Tenneco Midale 7-12-7-11 well (LSD 7-12-7-11 W2) where there is a large increase in the thickness of the Viking Formation at the expense of the Joli Fou. Other examples are shown in Figures 6 and 8.

The contact between the Viking Formation and the Big River Formation is conformable and lithologically gradational. The isopachous maps of the Formations show that the distribution of the Big River Formation is unaffected by the thickness of the underlying Viking Sandstone. Some local changes of Viking and Big River thicknesses with respect to each other have been considered in a previous section. These are unrepresentative of the general relationship between the Formations. The silty and sandy marker horizons within the Big River Formation are parallel to both the upper surface of the Viking Formation and the lower surface of the Second White-Speckled Shale in all of the stratigraphic sections. This indicates that the upper surface of the Viking Formation, apart from local anomalies, is quite even and conformable with the Big River Formation.

INTERNAL RELATIONS - VIKING FORMATION

In order to determine the stratigraphic relationships of the various elements that make up the Viking Formation, an internal correlation of these elements must be made. There is, however, a general absence of recognisable units within the Formation that can be correlated with confidence between the wells. This makes it difficult to determine the internal relations of the Viking Formation from the evidence of the stratigraphic sections.

Evans (1970) carried out an internal correlation within the western shelf Viking sandstones of southwestern Saskatchewan. This was done mainly by correlation of the many bentonites or bentonite rich shales in that area. These bentonites are recognisable by their relatively low resistivity. The opportunity for using such correlation markers in the Viking of southeastern Saskatchewan is restricted by their limited occurrence.

In making an internal correlation of the Formation the self-potential curve is of very little use because of the high shale content of the sandstone. This interlaminated shale tends to subdue the S.P. curve and in places cause it to become erratic and misleading. For this reason the resistivity curve is used as the basis for the correlation. The features correlated are the surfaces marking sharp transitions from low- to high-resistivity elements. Low resistivitiest may be created by such features as bentonite clay layers, bands of highly carbonaceous mudstone. High resistivities are attributed to siderite or calcite cementation. Nontheless the correlation of surfaces between wells are quite tenuous in places.

From the evidence of the electric well logs it appears that the Viking is a multistorey sand body. The term "multistorey" refers to the superposition of a sand body of one cycle upon one or more earlier ones, thus forming an unusually thick sand deposit (Pettijohn et al., 1965, p.134). The correlation of specific sandstone sub-units within the Formation is not possible, this is because generally the sandstones are either interlaminated with mudstones or siltstone, or show increased mud content either upwards or downwards. In these cases the resistivity curve tends to average out the reading, and the exact limits of the sub-units cannot be determined.

An internal correlation is attempted in two stratigraphic sections. These are extremely local, the closest possible spacing of available wells being taken in both. Figure 25 shows a northeast-southwest stratigraphic section in the southwest of the study area with a spacing of two wells per section. The resistivity curve for these wells is shown; the top of the Viking Formation is used as a stratigraphic datum. The two correlation surfaces taken appear to progressively slope from northeast to southwest. This indicates an offlap of units within the Formation in a southwesterly direction.

Figure 27 represents a detailed examination of the thick sand body at the western end of the stratigraphic section of Figure 8. The

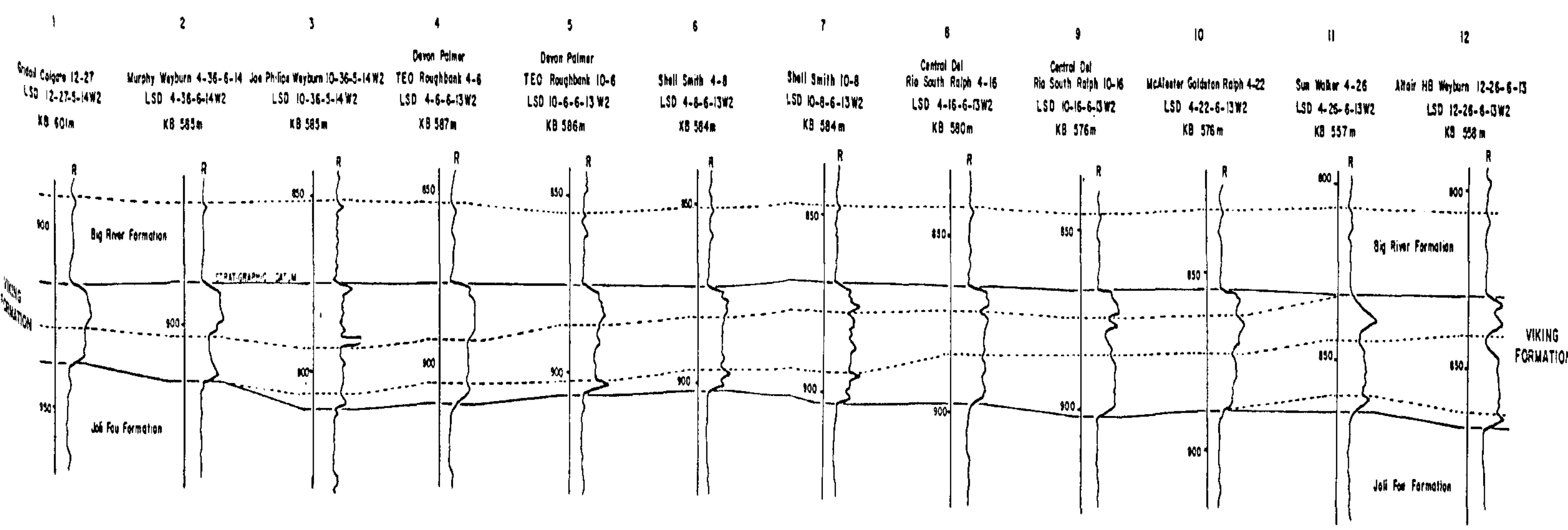


Figure -26 Southwest- Northeast Stratigraphic Cross Section : Internal Correlation of the Viking Formation.

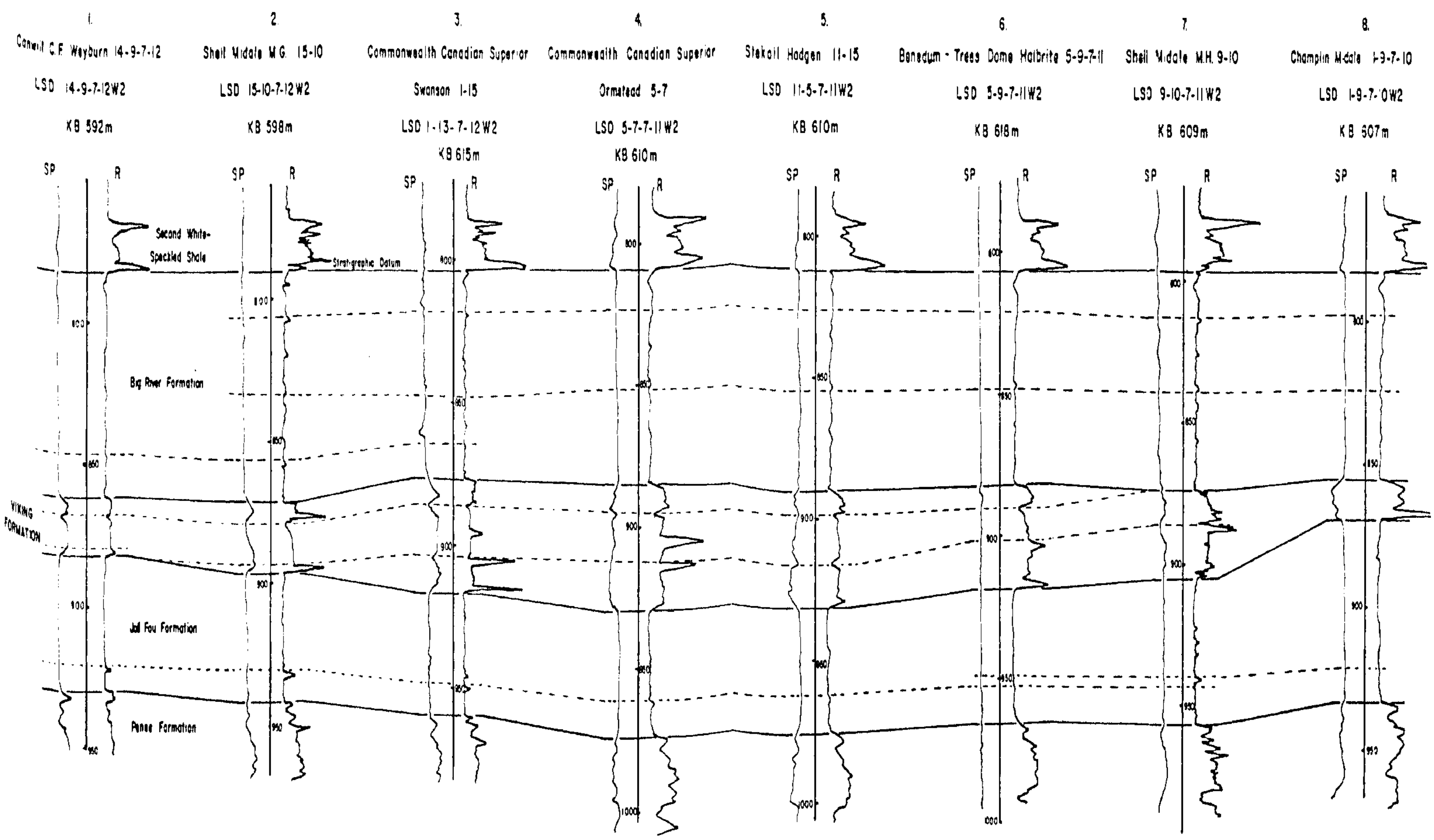


Figure - 27 West - East Stratigraphic Cross Section : Internal Correlation of the Viking Formation well spacing here is one per section. The stratigraphic datum is the base of the Second White-Speckled Shale. The two correlation surfaces show the same general relationship that was seen in Figure 25. The units offlap in a westerly direction.

Both of these sections indicate that internally the Viking Formation displays an imbricate relationship, offlap being in a westerly or southwesterly direction.

Evans (1970) recognised the presence of individual sandstone and shale members within the Viking Formation of southwestern Saskatchewan on the basis of resistivity profiles, taken at a well spacing of approximately seven per Township. His cross-sections show that the members display the same relationship but with offlap towards the east.

Not much reliance can be placed on internal correlations made within this Formation without adequate lithological control, such as would be provided by easily recognised bentonites or the matching of well core with logs. Any conclusions drawn from the correlations are, therefore, tenuous.

Depositional Environment

Simpson (1975) considered the Viking Formation in this area to be a tidal channel deposit. I shall, therefore, outline briefly the characteristics of tidal channel deposits.

Tidal channels are formed in association with nearshore, barrier island depositional systems. A recent synthesis of these systems has been presented by Reinson (1979). The best known and most important channel deposits are tidal-inlet fill sequences, which intersect the barrier island. Tidal channels are also formed in a back-barrier tidal flat setting.

The sands are fair to moderately sorted with a high grain-matrix ratio. They are generally fine- to medium-grained, subangular, with conglomerates occurring at the base. They contain argillaceous rock fragments, skeletal debris, carbonaceous material and collophane, possibly with glauconite and authigenic feldspar. Cementation is detrital and chemical. Bioturbation is widespread.

Tidal channel deposits have a fining upwards textural trend and generally reflect an upward increase in current flow conditions. Small scale sandstone structures are typical of those formed by tidal currents, they commonly include bi-directional cross-bedding, trough cross-bedding and ripple-laminae. A generalised depositional sequence for tidal channels is summarised by Reinson (1979) as follows: (1) An erosional base marked by a coarse lag deposit; (2) a deep channel facies consisting of sands with bi-directional, large-scale planar and medium-scale cross-bedding, and (3) a shallow channel facies consisting of sands with small- to medium-scale trough cross-bedding and washed out ripple laminae. Interbedded sand-silt and clay are present within back-barrier tidal channels, but absent from tidal-inlet channels due to higher energy conditions in this setting.

There is a wide variation in the geometries of tidal channel sands, from thin discontinuous sheets to thick multistorey bodies (Barwis and Makurath, 1978). Deposition of channel-fill sediments is a function of barrier migration. Lateral channel migration occurs concomitant with barrier island migration. The sand body deposited is elongated parallel to the barrier island, length is equal to distance of migration. It forms a trough shaped sand body with a thickness equal to the depth of the channel. It is disconformable with the underlying strata.

When marine transgression results in the inundation of this system, much of the barrier island sediments are reworked and redeposited. The sediments deposited in tidal channels are deeply buried and are thus not likely to be affected. They are more likely to be preserved than the overlying littoral and near shore deposits (Hoyt and Vernon, 1967). The resulting sand bodies have erosional upper and lower surfaces (Barwis and Makurath, 1978).

The reasons that Simpson (1975) considered the Viking Sandstone within this area to be a tidal channel deposit are: (1) The lobate, discontinuous form of the sand bodies, as described by Price (1963); (2) the fining-upwards associations within the Formation, and (3) the thick development of the Ashville Sands in southwest Manitoba. He considered these to be tidal channel deposits and regarded the environment of deposition as being continuous into southeastern Saskatchewan.

The author believes that the Viking Formation is not a tidal channel deposit for the following reasons:

(1) This study constitutes a more detailed examination of the Viking Formation in this area than has been done in the past by either Price (1963) or Simpson (1975). Consequently the lobate, discontinuous sand bodies which were previously thought to characterise the Formation in this area are now seen to be subordinate to the thick sheet sandstone described in this report. It is at least 300 kilometres in length and 120 kilometres in width. The author could not locate a description of a tidal channel deposit comparable in size to this sheet. According to Barwis and Makurath (1978) tidal-channel lithosomes may not be continuous beyond 50 kilometres, especially if beach and dune lithologies have been removed by erosion. Therefore, the areal extent of this sheet is too great for it to have had a tidal channel origin.

(2) The upper surface of the Viking in this area is conformable with Big River sediments. Tidal channel deposits are bounded above and below by disconformities.

(3) The presence of a coarse channel lag deposit, which is usually present at the erosional base of most channel deposits, is not detected at the base of the Viking in this region.

(4) All the Viking sediments in this region contain interbedded mud and silt. If these were deposited in tidal channels then these channels would be exclusively those of the back-barrier tidal flat environment. According to Reinson (1979) back-barrier tidal channel deposits are subordinate in extent to tidal-inlet channel deposits. One would expect that the sand sequence of tidal inlet channels, in

which silt and mud is absent, would also be represented in the area.

The only definite fining-upward relationship seen within the Viking lithologies of this area, apart from the graded storm layers, is the graded transition between the Viking Formation and the Big River Formation. This gradation is related to the onset of the deeper marine transgressive conditions that terminated Viking deposition.

A likely alternative environment for the deposition of the Viking Formation is a shallow marine shelf. This sand environment is not well understood. An adequate modern depositional analogue is not known, there is no well developed shallow-marine facies model. Many ancient sandstone deposits have, however, been interpreted as offshore marine sand bars and sheets. This has been done particularly by Cambell (1971) and Cotter (1975), who have summarised the characteristics of these deposits from examples known from the literature. A recent summary of shallow marine sands has also been carried out by Walker (1979).

These sands are characteristic of regressions. They are constructional features formed on marine shelves in depths of up to 200 m. The processes operating on these shelves are; (1) tidal currents; (2) meteorological currents - mainly wind, wave and storm generated currents, and (3) intruding ocean currents and density currents. (1) and (2) are by far the most important of these processes. Most deposits indicate the influence of both tidal and storm currents.

Lithologically these sand bodies are moderate to well sorted with a high grain-matrix ratio, they are fine-grained and tend to show good rounding. Variability of textural parameters is low. Coarse material if present is locally derived. Cementation is mainly chemical. Few argillaceous rock fragments or micas occur. Small amounts of feldspars, disseminated glauconite, collophane and small pebbles mainly of chert or local rock fragments are typically present. Abundant carbonaceous material and wood fragments are reported by both Cambell (1971) and Brenner and Davies (1974) within these sandstones and associated lithologies. Burrowing is typically well developed in this environment, often completely disorganising the lithological structure. The sandstones are stacked vertically and are separated by offshore mudstones and siltstones. Transitional sandstones containing 15 percent or more of mudstone matrix are present.

Sedimentary structures present within these sandstones are large scale cross-laminae, commonly with bipolar dips, and ripple cross-laminae, which are generally representative of tidal currents, and gently undulating sets of low-angle cross-stratification known as hummocky cross-stratification, which is indicative of storm dominated processes. According to both Cotter (1975) and Brenner and Davies (1974) high-energy storm-generated deposits are also frequently developed in this offshore environment, forming graded beds with erosive bases. A common feature in most ancient offshore, shallow marine sand bodies is a coarsening upwards sequence. According to Walker (1979, p. 81) a model of tidally-controlled shelf deposits based upon the present North Sea predicts the development of an overall fining upwards sequence. He concludes that the mechanisms responsible for coarsening-fining upwards relations in these modern and ancient deposits are not fully understood.

The geometry of these sand bodies is described as generally elongate bars or laterally continuous sheets with elongate, thicker and thinner parts, the direction of elongation being generally parallel to the projected shoreline. These bodies are formed on wide, shallow shelves and may occur up to 160 km from the associated shoreline. The dimensions of these sand bodies are quite variable. Campbell (1971) described an average offshore bar-lens as being about 6 m thick with a width of 3 km and a length of about 65 km. However, he says that two or more lenses may be superposed to form multistory sand bodies, and these dimensions may be increased by the various appropriate multiples. Brenner and Davies (1974) described regressive marine bar sands in the Upper Jurassic (Oxfordian) of Wyoming and Montana as forming an extensive sheet, covering an area of about 400 km by 800 km.

Internally these bars consist of beds, forming an imbricate pattern, parallel to the length of the bar with the youngest beds extending farthest seawards. They postulated to have been deposited by tidal currents. These currents, flowing at right angles to the shoreline, carried relatively coarse sand material, presumably from deltaic sources, and accumulated it as elongate shoals parallel to the shoreline.

The Viking sand sheet in the western part of the study area has an internal and external geometry that closely resembles a shallow marine offshore sand sheet. The Viking sandstones are lithologically similar to those found in this type of deposit.

The uneven, thin, discontinuous sand bodies deposited to the east of the Viking sand sheet were formed from the same material, and deposited in an environment similar to the sheet sandstone. They probably formed as thin, individual marine bars and sand ridges. This would account for the thin discontinuous, lobate forms of the deposits in this area.

A major feature of these eastern sands, however, is their clearly defined erosive base. One would expect that a marine bar or sand ridge would be deposited upon a reasonably flat base. A study of many modern, tidally deposited, marine sand bars and ridges in a shallow offshore environment has been carried out by Off (1963). He noted that many are not deposited with flat bases, but occur within a closed depression. He stated that concurrently with the deposition of this sand the ocean floor was being eroded into troughs by tidal currents. Any subsequent movement of this material due to further current activity, such as wave- or storm-generated currents, he feels, could have deposited this material into these troughs. It is also possible that, following the formation of these troughs, deposition within them may have been carried out by subsequent tidal currents rather than by movement of previously deposited sediments.

The deposition of the Viking sand sheet may have been localised by a linear structural feature. The presence of a north-northeast trending structural linear between Ranges 8 and 9 W2 has been considered in a previous section. At the time of Viking deposition, this may have formed a break in the slope of the shallow marine shelf, upon which these sediments were deposited. The break in slope would have localised the deposition of this material and thereby thickened it. According to Campbell (1971) a decrease in gradient of probably less than one degree caused by such a break in slope of a gently dipping shelf, would cause localisation of sedimentation.

Tidal currents sweeping transversely over this feature would deposit sediment. As this process continued the depositional front would move seaward, thus building up the sheet. Internally this sheet would be imbricated with the younger sediments farthest from shore. The depositional model is illustrated by Figure 28.

The position of the associated shoreline would be towards the east. The shoreline would have been either parallel or sub-parallel to the length of the sand sheet. The lack of a shelf to shore facies makes it difficult to determine the distance of this body from the shoreline.

The western-derived Viking sands of west and central Saskatchewan form a well documented, continuous sequence of near-shore deposits, shoreface and barrier sands in western Saskatchewan, to shelf sandstones represented by tidal sand ridges in west-central and central Saskatchewan (Evans,1970; Simpson,1975). The absence of a shelf-to-shore sequence in eastern Saskatchewan is explained by the contrast in sediment supply. Whereas great volumes of material were available from the western Cordilleran source, the supply of sand from the low cratonic foreland in the east was too small to permit the spread of a continuous deposit across the shelf. An example of a similar situation has been noted by Campbell (1971) from the Upper Cretaceous of New Mexico.

In conclusion therefore, it is noted that many features of the Viking in this area are common to both tidal channel deposits and to tidal deposits on shallow marine shelves. The geometry of the sheet sandstone body, however, closely resembles that of a shallow marine shelf sandstone. This form is uncharacteristic of tidal channel

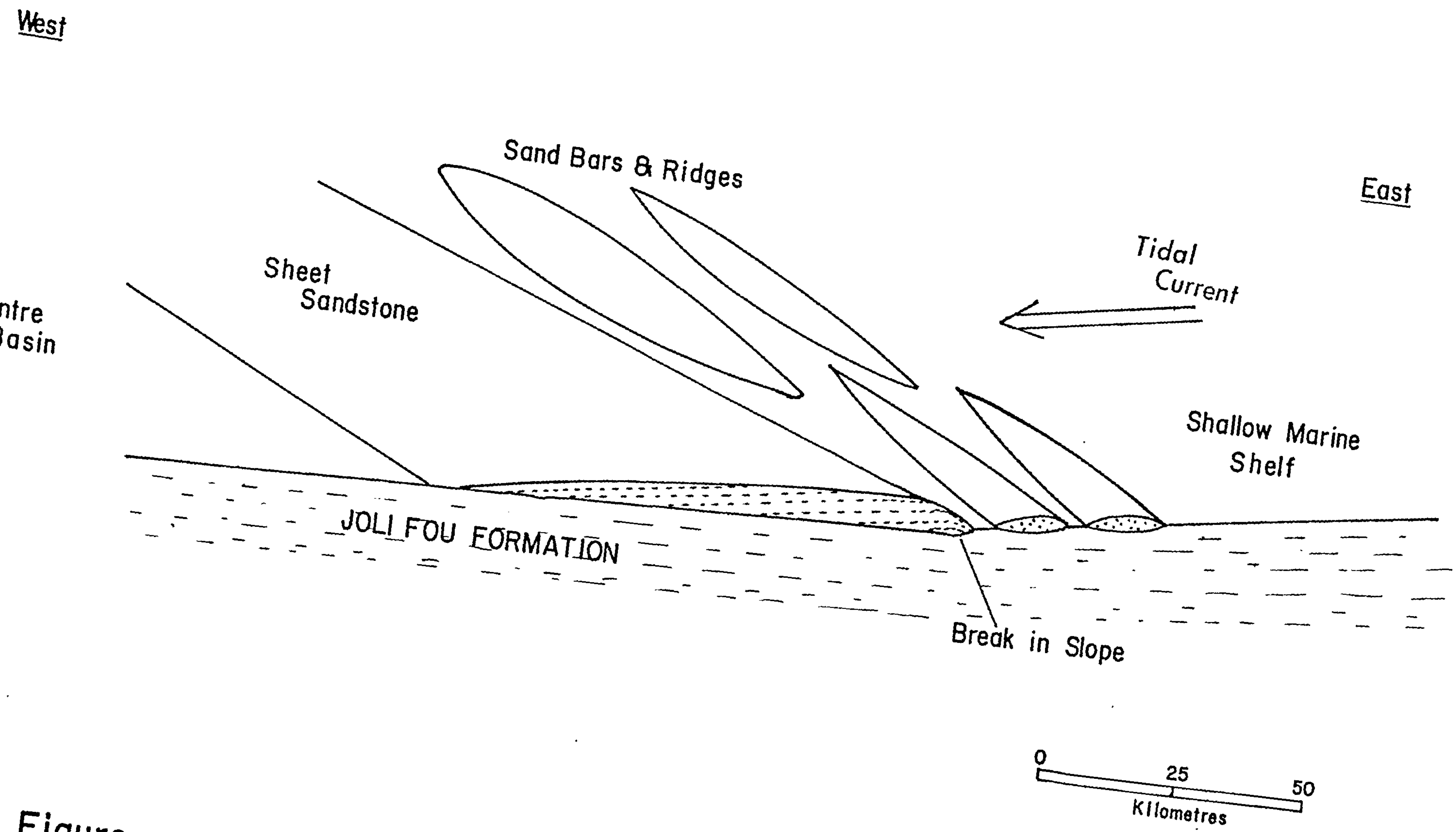


Figure-28 Depositional Model - Viking Sandstone in Southeastern Saskatchewan.

deposits.

Arrival at a definitive conclusion as to the origin of the Viking in this area would be facilitated by: the recognition of characteristic depositional cycles within core, and a detailed investigation of Viking-Ashville depositional environments. It may be that the area of study is a transitional zone of mixed environments.

HYDROCARBON POTENTIAL

Hydrocarbon production from the Viking Formation has been restricted entirely to the western shelf sediments eastern Alberta and west-central Saskatchewan. In the latter the main production is from reservoirs of the Dodsland-Hoosier pool complex (Evans, 1970).

The formation of these oil reservoir structural-stratigraphic traps is attributed to three factors (Jones, 1961). Firstly the southerly regional dip forms a primary structural trap. Secondly, the general attenuation or thinning of the Viking Formation to the north and east. This forms a stratigraphic trap. Thirdly the broad, low-amplitude folds, which mimic the pre-Cretaceous topography; these form secondary structural traps.

Viking thicknesses in the Dodsland-Hoosier production area are between 12 m and 21 m. These consist of imbricate, multistorey sheet sandstones, laid down by tidal currents in a far-from-shore marine environment, Evans (1971). The principal commercial reservoir rocks are silty and muddy sandstones and sandy mudstone-siltstones. The sandstones are fine-grained, glauconitic and carbonaceous. They contain discontinuous mudstone partings. Coarse sand pebble grade sandstones are present but are relatively uncommon.

The hydrocarbon is sealed within the Viking by the argillaceous units that occur above and below, and are intercalated within the Formation (Christopher et al., 1971). An alternative method of entrapment has been proposed by Simpson (1979), whereby greatly increased induration within the sandstone is created by precipitation of mineral cements, thus providing a cap rock within the Formation.

The framework for the accumulation of hydrocarbons in the Viking of western Saskatchewan are present within the Viking of southeastern Saskatchewan. The primary structure is the same in that there is a relatively steep regional gradient towards the south. There are excellent potential stratigraphic traps provided by the attenuation of the sheet sandstone body to the east and west, and by the lenticularity of the sand bars and ridges in the east. The presence of secondary structural traps formed by draping over pre-existing topographic features, has also been demonstrated.

The sheet sandstone is similar or greater in thickness than that in the Dodsland-Hoosier area. It is similar lithologically, except that it lacks the coarser grained element, seen in the west. It contains much intercalated mudstone, the sands have a generally high mudstone content similar to those of the low porosity reservoir sands of the western Viking. The widespread bioturbation is likely to break up the shale partings which separate the various possible sandstone reservoir elements. At the same time, however, extensive bioturbation may decrease reservoir quality by reducing the effective permeability (Boethling, 1977). The bands of siderite and calcite, form an effective reservoir seal at many levels within the Formation. The Formation is completely enclosed by shales which may also create a significant trapping mechanism.

Two different origins have been proposed for the hydrocarbons within the Viking of western Saskatchewan (Christopher et al., 1971). The first maintains that the surrounding shales acted as the source lithologies. It is proposed that hydrocarbons were driven out of the Big River and Joli Fou muds and concentrated within the Viking by compaction of the succession. The second proposes that the Viking accumulation is of Palaeozoic origin, and represents the light fraction of heavy oils found at the pre-Cretaceous unconformity. This fraction would have passed through the underlying shales, probably by osmosis, and was trapped wiithin the Viking.

The criteria neccessary for at least the first of these cicumstances is met within southeastern Saskatchewan. There is a high percentage of organic material present in the Joli Fou and the Big River Formations and in the Viking Formation itself. These could well act as a source for hydrocarbons.

There are many promising structural and stratigraphic trends within the Viking Formation of southeastern Saskatchewan. The most promising trend appears to be that formed by the north northeast-south southwest trending 30-40 m thick sand body at the eastern edge of the sheet sandstone, in the central part of the area. This body abruptly pinches out updip to the east into shales or thin to thicknesses of 5 m or so. This is illustrated in a structural fence diagram shown in Figure 29.

This sheet sandstone attenuates to the west and good stratigraphic traps may be provided also by this pinchout in association with the regional dip. The discontinuous nature of the marine sand bars and ridges in the eastern part of this area, where many attenuate and pinch out, provides a promising stratigraphic prospect, particularly where sand thicknesses greater than 10 m, are locally developed.

Supratenuous fold structures above Mississippian topographic features appear to have their maximum development in the eastern and

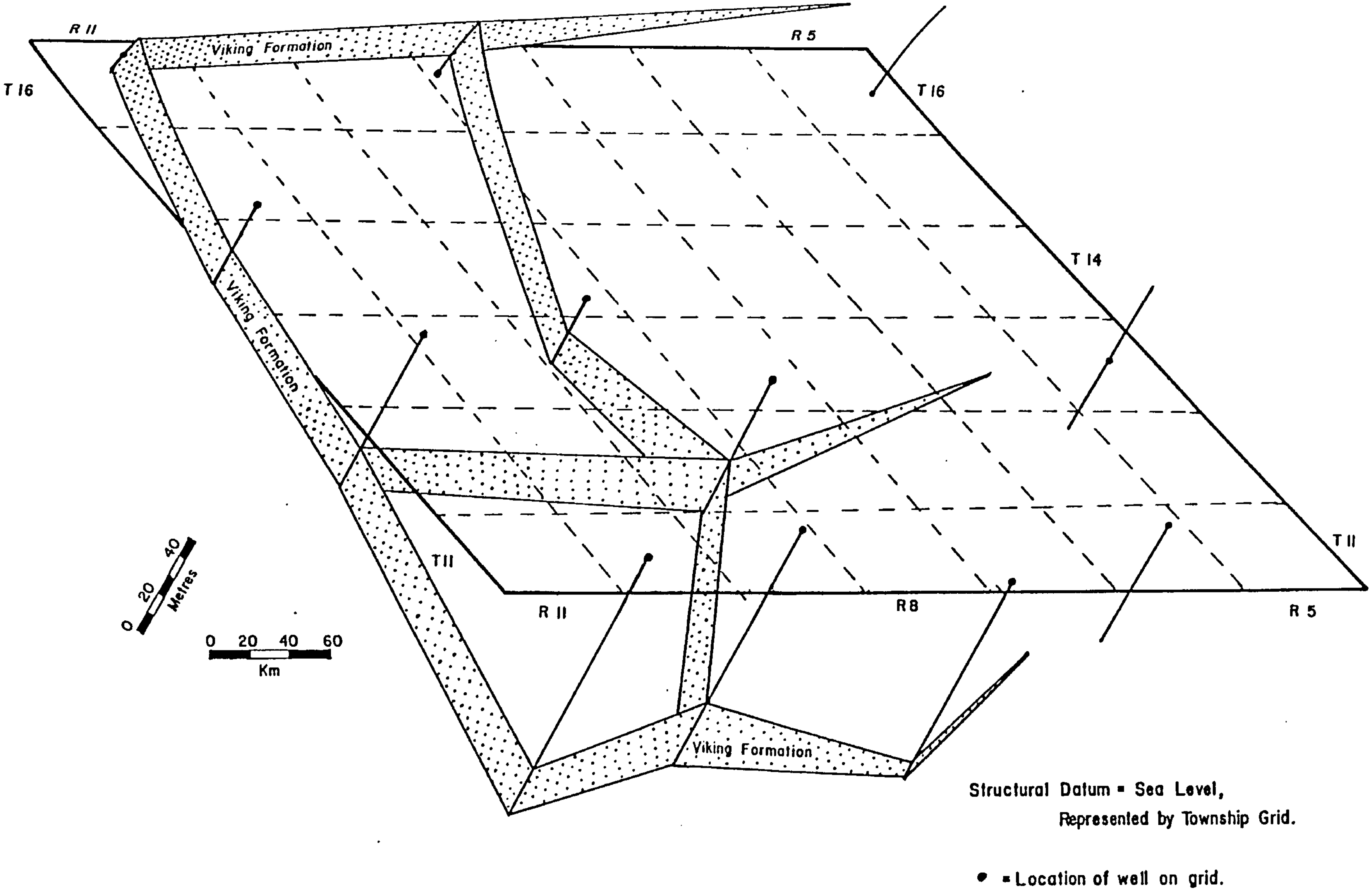


Figure - 29 Structural Fence Diagram, Viking Formation, Southeastern Saskatchewan.

eastern-central parts of the area. The Viking sand in this region is thin and discontinuous, but coincide with the domal features and therefore form quite good prospects..

It is worthwhile investigating the region, where the dissected Mississippian edge is traversed by thick Viking sheet sand in the region of Townships 10 and 11, Range 8 W2. It is highly probable that domal features are present similar to those east of this region.

Salt-collapse structures also may create potential hydrocarbon reservoirs. Extensive fracturing and collapse, which result from localised salt removal, may cause vertical movement of hydrocarbons into the crest of the structure (Wilson et al., 1963). An example of this from the Upper Devonian Outlook Field in North Dakota is outlined by Parker (1967). The large solution generated depression in the southwest of the study area was formed after Viking deposition and the adjacent anticlinal nose forms a local high. The smaller collapse feature was formed in Joli Fou times in an area of Viking non-deposition. These structures are worthy of investigation as they may be recipients of hydrocarbons from underlying Palaeozoic reservoirs.

Numerous hydrocarbon showings have been reported from the eastern shelf Viking Sandstones and its southern equivalents, of which 15 from southeastern Saskatchewan are tabulated in Table IV. These were reported usually as bubbles of gas.

There is major production from the Muddy Sandstone in northeast Wyoming and southeastern Montana. There has been none, however, from this Formation in North Dakota, or any other part of the easterly derived Newcastle Sandstone although many oil showings have been

Well Name	Location	Depth Below K.B.	Type of Showing
Sohio Western Pete Tiny 1	01-14-05 W2	260-265	Gas
B.A.Husky Phillips Hyde 1	12-28-19-07 W2	471-476	G.C.W.
B.A.Husky Phillips Springside 1	08-29-27-07 W2	338-346	G.C.W.
Sohio Consolidated Allenbee O&G Okla 1	01-01-35-08 W2	433-437	G.C.M.
Imperial Okla 1-29-35-8	01-29-35-08 W2	382-392	G.C.M.
Imperial Bures 7-16-36-8	07-16-36-08 W2	375-395	G.C.M.
B.A. Husky Phillips Kegworth 14-11	14-11-14-09 W2	654-718	G.C.W.
Gill 3-8	03-08-07-10 W2	867-875	G.C.W.
Bennet Burns & Ben L. Young Bell 1	11-19-05-14 W2	917-926	G.C.W.
Socony Weyburn	08-11-08-14 W2	809-818	G.C.S.W.
B.A. Husky Phillips Vibank 1	05-29-15-14 W2	692-699	G.C.W.
Richfield B.A. Home Colfax 7-10	07-10-11-15 W2	731-755	Oil C.M.
Agro Hurd 10-9	10-09-17-15 W2	693-696	G.C.S.W.
Socony Central Leduc Del Rio West Ratcliffe	13-22-01-16 W2	1186-1198	G.C.W.
British American Williston Brightmore 1	09-28-09-16 W2	758-763	G.C.W.

Table IV Hydrocarbon Showings in the Viking Formation in Southeastern Saskatchewan.

reported. Four oil showings were reported from the Newcastle of southwest and west-central North Dakota by Anderson (1969). Wulf (1964) has reported two showings in the Newcastle of southwest North Dakota, five in southeast Montana and two in northwest South Dakota.

Both Wulf (1964) and Anderson (1967) have noted that on many wells drilled in this area a geologist was not present until the drill penetrated below the Newcastle Sandstone. A similar situation may have existed in southeastern Saskatchewan, where the primary drilling target has usually been the Mississippian and not the uppermost formations in the section. It is likely, therefore, that hydrocarbons in the Viking and Newcastle Sandstones of these wells have been overlooked.

The fact that many widely distributed hydrocarbon showings have been noted reinforces the prospective character of the Viking Formation. It would seem worthwhile to test the optimum structural-stratigraphic configurations of the Formation within this area. A further attractive economic consideration is the relatively shallow depth of this formation and the overlay of soft shale and sands allowing for considerable ease of drilling.

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THE PLATES

EXPLANATION OF PLATES

The scale given in all Plates is 1 cm, unless otherwise stated. Depths given are the number of metres the sample was located below K.B..

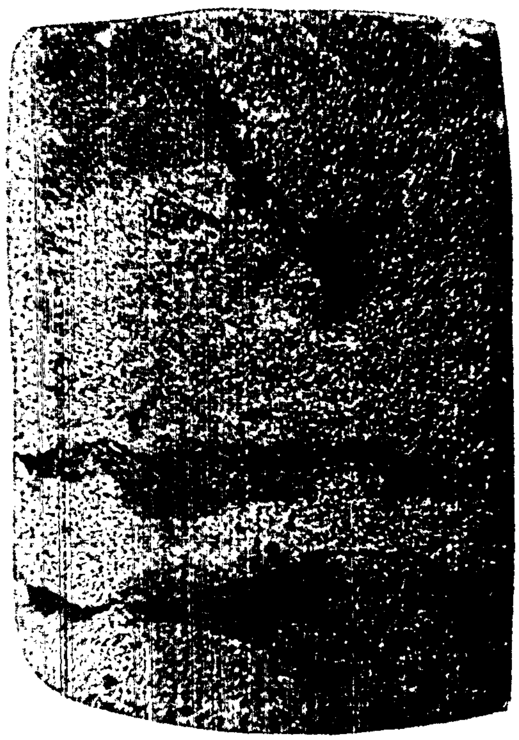
PLATE 1

A. Siderite-Limonite Cementation within sandstone. Viking Formation. Richfield B-A Williston Sandercock 10-28 (LSD 10-23-9-15 W2), 765.6 m.

B. Burrows of _Teichichnus_. Muddy sandstone. Viking Formation. Socony Central Del Rio West Ratcliffe 22-13 (LSD 13-22-1-16 W2) 1190 m.

PLATE 1

B.



A.

PLATE 2

A. Undulating Lamination; Low Angle Bi-directional Cross-Lamination. Viking Formation. Oungre 1 (LSD 7-1-2-14 W2). 1155.6 m.

B. Low-Angle Bi-directional Trough Cross-Lamination; Vertical Burrows infilled with Sandstone. Viking Formation. Oungre 1 (LSD 7-1-2-14 W2). 1157 m.

A.

PLATE 2

B.

PLATE 3

A. Wavy Bedding and Isolated Starved Ripples. Viking Formation. Oungre 1 (LSD 7-1-2-14 W2). 1156 m.

B. Graded sand-silt-mud units. Viking Formation. Socony Central Del Rio West Ratcliffe 22-13 (LSD 13-22-1-16 W2). 1189 m.

A.

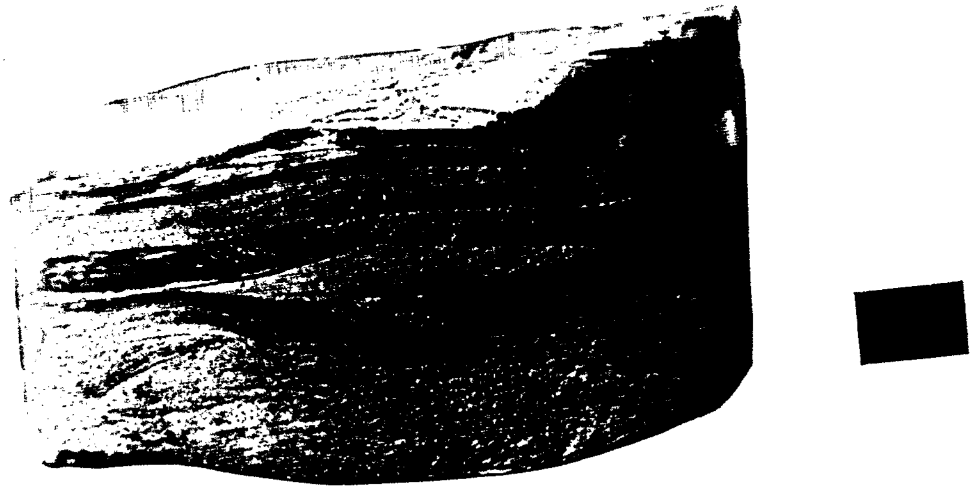


PLATE 3

B.

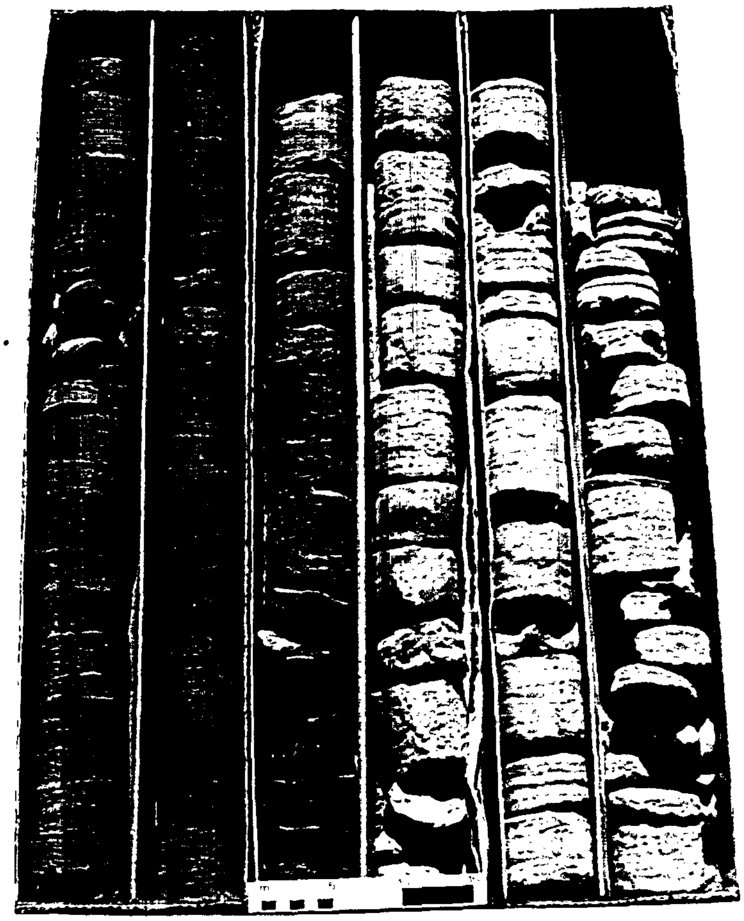
PLATE 4

A. Graded Viking-Big River Contact. Base of core is at bottom right hand corner, top of core is at bottom left hand corner. Imperial Canadian Superior Martin (LSD 1-3-12-31 W2). 1800-1815 m.

B. Pyrite- Chalcopyrite Burrow Infill. Viking Formation. Imperial Stillman 1-8-4-5 (LSD 1-8-4-5 W2). 928.9 m.

PLATE 4

A.



B.

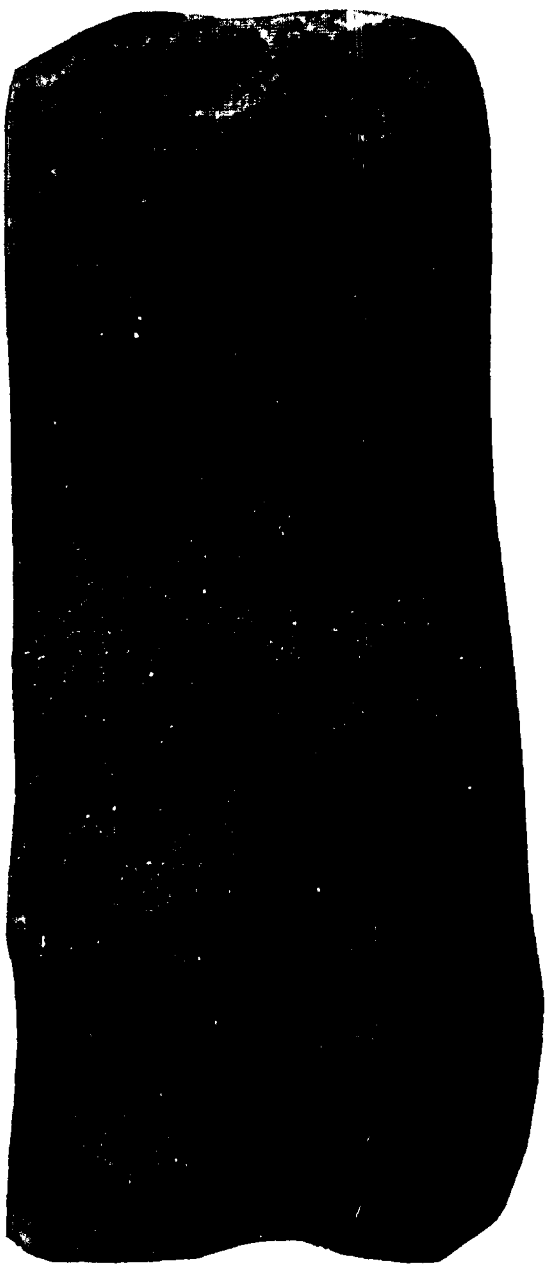
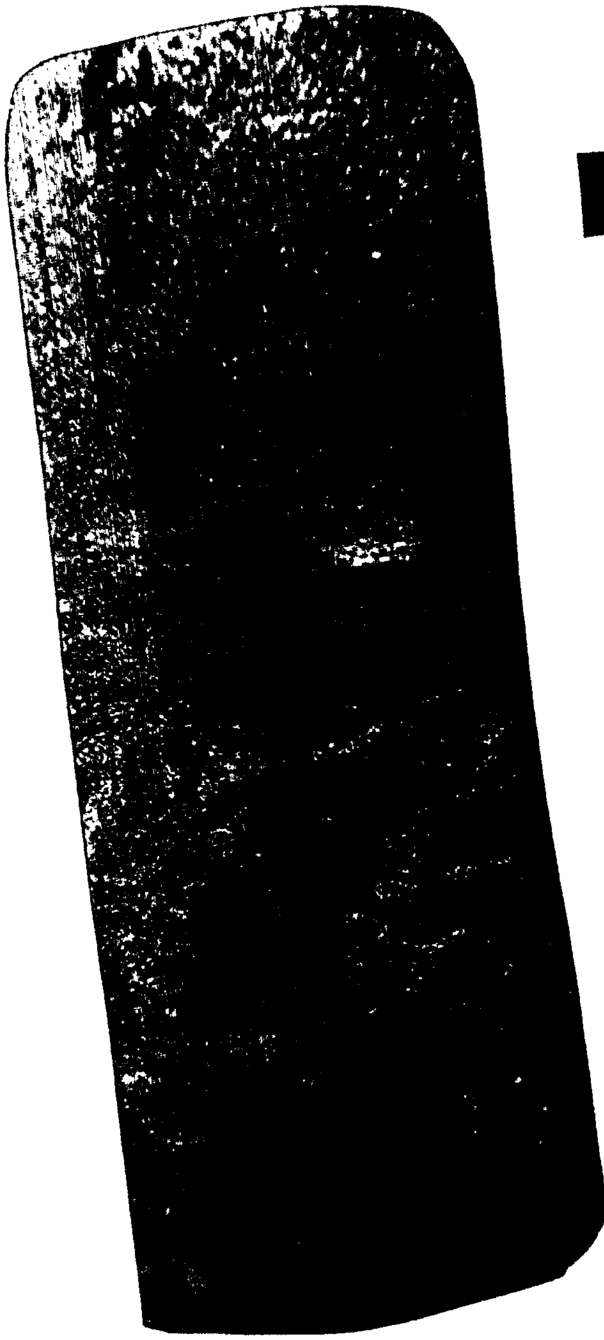


PLATE 5

A. Carbonaceous Material within Sandstone. Viking Formation. Socony Central Del Rio Tribune 31-12 (LSD 12-31-3-14 W2). 1024 m.

B. Angiosperm Leaf, Muddy Sandstone. Viking Formation. Socony Central Del Rio West Ratcliffe 22-13 (LSD 13-22-1-16 W2). 1190.8 m.

PLATE 5



A.

B.

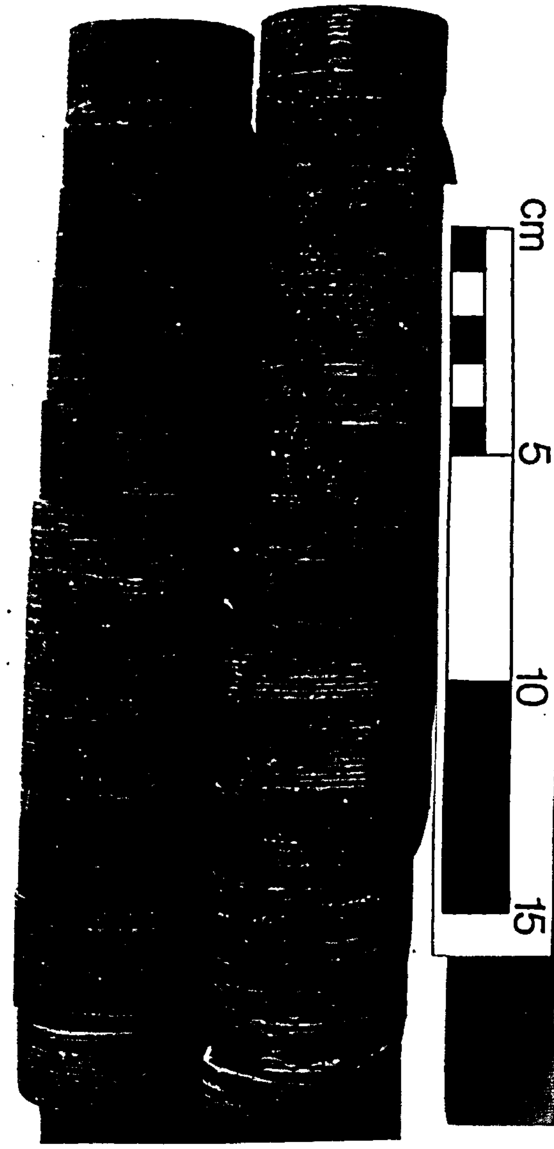
PLATE 6

A. Pteridophyte Stem in Siltstone. Viking Formation. Richfield B.-A. Williston Sandercock 10-28 (LSD 10-28-9-15 W2). 768.9 m.

B. Mudstone. Big River Formation. Imperial Stillman 1-8-4-5 (1-8-4-5 W2). 923.8 m.

PLATE 6

B.



A.

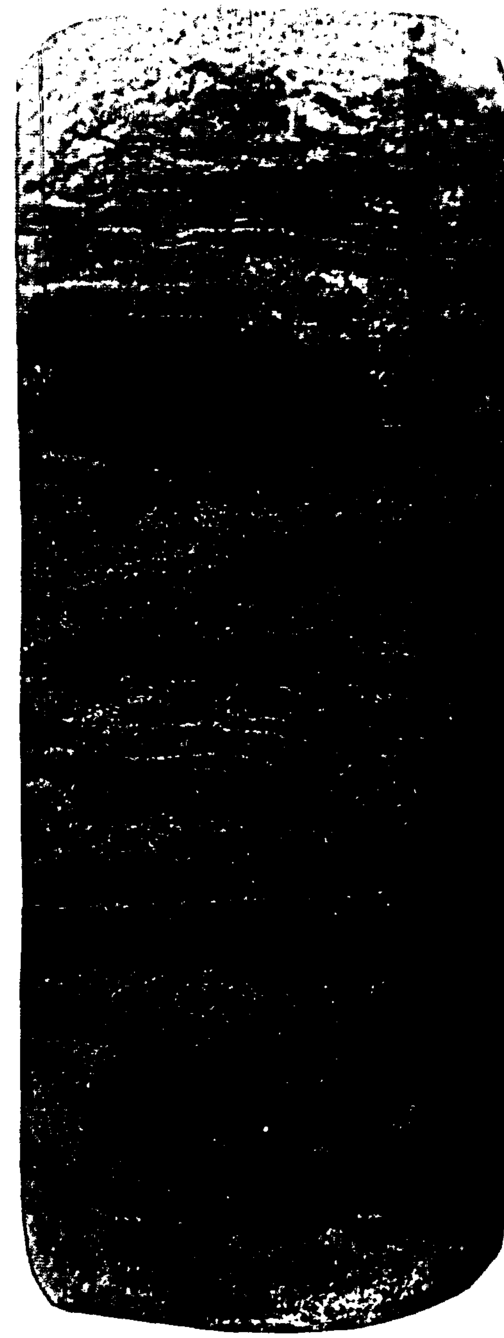
PLATE 7

A. Ptygmatic Folding, Sandstone and Mudstone. Big River Formation. Socony Central Del Rio Grassdale 1 (LSD 6-2-7-16 W2). 892 m.

B. Fish-Skeletal Debris, Mudstone. Big River Formation. Imperial Canadian Superior Martin (LSD 1-3-12-31 W2). 548 m.

<u>PLATE 7</u>

A.



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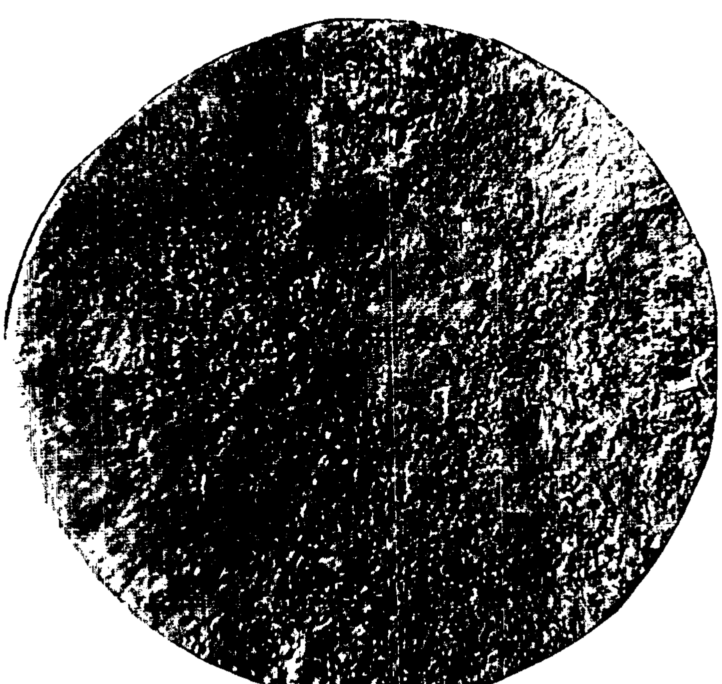

APPENDIX I

Lithologic Descriptions of Selected Cored Sections from the Lower Colorado Succession in Southeastern Saskatchewan.

Socony Central Del Rio Grassdale 1
LSD 6-2-7-16 W2

K.B. 616.3 metres

Depth below K.B. (Metres)	
	Big River Formation
890-894	Sandstone and mudstone. Light grey (N7) very fine grained quartzitic sandstone is closely interlaminated with medium grey (N5) to medium dark grey (N4) mudstone. Loading structures are common at the sand-mud interfaces, small scale ptygmatic folding and sand injection features also occur. Many sand filled burrows are present.
894-895.5	Core missing.
895.5-896.1	Siltstone. Medium dark grey (N4). Non-calcareous.
896.1-897.6	Sandstone and mudstone. As described for the interval 890-894m, except that the sandstone contains kaolin, muscovite and carbonaceous plant debris.

Socony Central Del Rio West Ratcliffe 22-13
LSD 13-22-1-16 W2

K.B. 712.3 metres

Depth below K.B.
(Metres)

Big River Formation

1179.6-1179.9	Siltstone. Light olive grey (5y 6/1) horizontally laminated, non-Calcareous. Repeatedly grades upwards into thin layers of medium dark grey (N4) mudstone.
1179.9-1188.7	No core.

Viking Formation

1188.7-1190.8	Sandstone and siltstone. Light grey (N7) very fine grained, quartzose sandstone occurs in layers up to 5cm thick. These grade upwards into light olive grey (5Y 6/1) siltstone which grades into dark grey (N3) mudstones less than 1cm thick. Discontinuous sandy layers occur within the siltstone. A 2cm thick layer of sandstone with brown siderite cement occurs at 1188.9. A ubiquitous fine horizontal lamination is present, this is occasionally undulating and may be disrupted by sand injection. Small vertical and horizontal sand filled burrows are present. Occasional small black organic fragments are seen. <u>Teichichnus</u> is well developed. There is an increase in mudstone towards the base and a gradual contact with
1190.8-1193.9	Sandstone. Light grey (N7), fine-grained, quartose and kaolinitic. Induration is moderate to poor, increasing upwards. It contains abundant well preserved black carbonaceous plant fragments, in places these form continuous horizontal layers. Horizontal and vertical sand filled burrows are present. Thin muddy laminations occur, these decrease in frequency towards the base of the interval.

1193.9-1194.3 Carbonaceous mudstone. Black (N1) to greyish black (N2), very brittle. Is sharply bounded at top and bottom.

1194.3-1197.9 Sandstone. As described for the interval 1188.7-1190.8. Is extensively bioturbated, many sand filled burrows are present. A thin light grey (N8) bentonite layer occurs at 1196.6 m, it is 2cm thick and is immediately succeeded by a 2cm thick layer of sandstone cemented by siderite.

Mobil CDR Flat Lake 12-30-1-15
LSD 122-30-1-15 W2

K.B. 712 metres

Depth below K.B.
(Metres)

Viking Formation

1199.1-1202.1	Sandstone and mudstone. Light grey (N7) quartzose, fine grained sandstone is intercalated with medium grey (N5) mudstone. Loading Features and small scale deformation at the sand-mud interface are present. Burrows filled with sand are common, *Teichichnus* is present, there is extensive bioturbation. Sections of poorly indurated sandstone without mudstone, up to 12 cm thick are present. There is increasing mudstone present towards the base. A .1 metre thick unit of mudstone is present at 1202. This is medium grey (N5) and is packed with black carbonaceous plant fragments. Fracturing and faulting indicated by slickensides, is present within the mudstones.

Mobil Oil South Grassdale 32-10
LSD 10-32-6-15 W2

K.B. 594 metres

Depth below K.B.
(Metres)

Joli Fou Formation

921.1-933.9	Mudstone. Medium dark grey (N4). Non-calcareous. Contains fish-skeletal debris. Has been extensively bioturbated in parts. Contains very fine-grained, horizontally laminated sand layers, up to 5cm thick. Sandy patches in bioturbated areas are highly glauconitic at 933.6.
933.9-936	Sandstone. Light olive grey (5Y 6/1) fine grained, quartzose. Is well laminated with prominent cross lamination with low angle planar foresets. Towards the top of the section the sandstone becomes kaolinitic and has extensive mudstone laminae. Inoceramus shell fragments are present. A Mudstone layer 10cm thick is present at 935.6 m. The sandstone grades into
936-941.6	Mudstone. As in interval 921.1-933.9.

Richfield-BA-Williston-Sandercock 10-28
LSD 10-28-9-15 W2

K.B. 575.1 metres

Depth below K.B.
(Metres)

Big River Formation

758.9-763.8	Siltstone. Medium grey (N5) with a poorly developed horizontal lamination. Contains occasional black carbonaceous plant fragments. A very light grey (8 N8) bentonite layer, 12cm thick and containing small crystals of biotite occurs at 763.2 m.

Viking Formation

763.8-766.3	Sandstone. Light grey in colour (8 N8). Fine grained, quartzose. Is rich in carbonaceous plant fragments towards the top of the interval. Is poorly indurated at the top of the interval becoming well indurated down section. Medium grained chert fragments are present. Sideritic concretions occur at 765.6 m.
766.3-767.5	Sandstone and mudstone. Sandstone as described for interval 763.8-766.3 m is intercalated with thin, horizontal layers of dark grey (N3) mudstones. Loading structures and organic traces are present at sand-mud interfaces.
767.5-768	Siltstone. As described for interval 758.5 - 763.8 m.
768-768.2	Sandstone. Light olive grey (5Y 6/1) quartzose, containing very thin muddy laminations. Is cross bedded with low-angle planar foresets. Is rich in carbonaceous plant fragments.
768.2-768.8	Siltstone. As in interval 767.5-768.2 m. Contains well preserved intact plant fragments.
768.8-770.2	Sandstone. Light grey (7 N7), quartzose, fine grained, without internal lamination. Contains carbonaceous plant debris. Becomes silty in parts. Is extensively bioturbated and contains flattened sand filled burrows.

Oungre 1
LSD 7-1-2-14 W2

K.B. 672.4 metres

Depth below K.B.
(Metres)

Viking Formation

1155.2-1159.8	Sandstone. Light grey (N7) to light olive grey (5Y 6/1), fine grained and quartzose containing medium grey (N5) and medium dark grey (N4) mudstone laminations. The sandstone is cross laminated in parts, with low planar foresets dipping gently in opposite directions. Trough-cross lamination is also present. Wavy-bedded sandstone and starved ripples are also present. Horizontal and sand filled burrows are common. Induration is moderate.

Socony Central Del Rio Tribune 31-12
LSD 12-31-3-14 W2

K.B. 616.6 metres

Depth below K.B.
(Metres)

Viking Formation

1021.4-1022.9 (20% Recovery)	Sandstone. Light grey (7N7), very fine grained, quartzose, with soft black carbonaceous plant fragments. Moderate to poorly indurated.
1022.9-1023	Sandstone, siltstone. The siltstone is medium dark grey (4N4) and contains patchy, thin, irregular layers and lenses of light grey (7N7) very fine-grained sandstone. The sandstone contains small sand filled burrows and black carbonaceous plant fragments. The sandstone and siltstone are in sharp wavy contact which displays loading features.
11023-1024.1	Silty sandstone. Medium grey (5N5). Very fine grained, quartzose. Horizontal layering has been disrupted by bioturbation. Many horizontal, flattened sand-filled, tubular burrows are present. Black carbonaceous plant fragments occur. It is well indurated and becomes increasingly silty towards the base, where it is in sharp contact with
1024.1-1024.7	Sandstone. Light grey (7N7), quartzose, fine-grained, poorly indurated becoming flaggy towards the base. Contains vertically arranged, black, carbonaceous plant fragments.

Shell Midale A-7-18
LSD 7-18-6-10 W2

K.B. 609.6 metres

Depth below K.B.
(Metres)

<u>Viking Formation</u>

894.6-897.6* Sandstone. Light grey (7N7). Fine- to medium-grained, it is quartzose with patches of calcareous cement. Bands up to 15 cm in thickness occur in which the sandstone contains abundant grains of medium sized red cherty material. A segregation of calcite 2 cm thick is present. The section has a faint horizontal lamination. Grain size generally increases upwards.

* 50% Recovery

Imperial Federated Coop Palmer North Portal 12-29
LSD 12-29-1-5 W2

K.B. 579.1

Depth below K.B.
(Metres)

<u>Big River Formation</u>

1029.3-1030.5	Siltstone. Medium dark grey (4N4). Has a fine horizontal lamination. Contains sparse fish-skeletal debris.
1030.5-1032	Sandstone. Light grey (7N7), very fine-grained, quartzose. Contains abundant carbonaceous plant fragments, increasing towards the base. Some fragments are vertical. It is bioturbated, sand filled burrows occur. <u>Teichichnus</u> is present. It is poorly indurated at the top of the section, becoming well indurated at the base.
1032-1033.2	Siltstone. Medium dark grey (4N4). Poorly laminated, contains many sand filled burrows and a few thin discontinuous sandy layers.

Imperial Stillman 1-8-4-5
LSD 1-8-4-5 W2

K.B. 591.6 meetres

Depth below K.B.
(Metres)

Big River Formation

923.8-926 Mudstone. Medium dark (4N4), horizontally laminated with rare fish-skeletal debris. A light greenish grey (5GY 8/1) bentonite layer 3 cm thick occurs at 924.3 m. A white calcite segregation 3 cm thick occurs at 924.4. Vertical slickensides occur within the mudstone. Grades into

Viking Formation

926-927.5(?) Sandy mudstone. Contains thin irregular concentrations of sand, is light grey (7N7) with kaolin and abundant black carbonaceous fragments. At 926.1 m there is a band of black carbonaceous mudstone. The sandy mudstone is well indurated and grades into

927.5(?)-929 Sandstone. Light grey (7N7) to light olive grey (5Y 6/1). Very fine-grained with abundant carbonaceous plant debris. Contains a horizontal silty lamination in parts, which has been disrupted by bioturbation. In places the lamination is undulating and in one instance forms a cross lamination with very low angle planar foresets. Sand filled burrows oblique to the horizontal lamination are present. From 928.5 m downwards there appears small segregations of pyrites and chalcopyrites. At the base of the core these form segregations up to 5 cm in length. Sideritic cementation is present and small rounded phosphate nodules occur. It is extremely well indurated and represents an increase in induration from the interval above.

Imperial Tidewater Wapella 9-33-14-1
LSD 9-33-14-1 W2

K.B. 598.3 metres

Depth below K.B.
(Metres)

Joli Fou Formation

584.9-601 Mudstone. Medium grey (N5). Non-calcareous. Has well developed horizontal lamination, bottom surfaces show occcasional traces of scouring. Contains occasional layers of very fine-grained horizontally laminated quartzose sandstone up to 2 cm thick, some of which show sand injection structures into the surrounding mudstone. A sideritc concretionary layer 7 cm thick occurs at 593.7 m. A small phosphate nodule, 3 cm long, is present at 596.8.

Imperial Canadian Superior Martin
LSD 1-3-12-31 W1

K.B. 585.8 metres

Depth below K.B.
(Metres)

Big River Formation

544-550.2	Mudstone. Medium dark grey (4N4) in colour. Horizontally laminated. Contains fish-skeletal debris, including well preserved spines and teeth, both as scattered fragments and in packed discrete layers. Contains discontinuous patches of very fine grained light olive grey (5Y 6/1) sandstone less than 1mm thick, which is glauconitic in places. Mudstone becomes sandy at 546.5 m forming a band 22cm in thickness. The mudstone grades into a
	Viking Formation
550.2-550.5	Muddy sandstone. Light olive grey (5Y 6/1), fine-grained, without lamination. Contains flattened tubular burrows lined with sand and filled with mud. Mudstone content decreases towards the base of the interval. Grades into
550.5-553.2	Sandstone. Light grey (N7), fine-grained quartzose, kaolinitic. Contains scattered fish-skeletal debris. Is medium to well indurated, increasing towards the top of the interval. Becomes flaggy at the base.

APPENDIX Ia

Lithologic Description of Cored Section, Lower Colorado Succession Southeastern Saskatchewan, taken from outside the selected study area.

Imperial Esk 7-14-33-20
LSD 7-14-33-20 W2

K.B. 1767 metres

Depth below K.B.
(Metres)

Big River Formation

407.2-415.7	Mudstone, medium grey (N4). Becomes increasingly silty with depth. Scattered fish skeletal debris is present. Irregular patches of very fine-grained, olive grey (5Y 6/1), quartzose sandstone, less than 2mm in thickness occcur. Light bluish grey (5B 7/1) bentonites, several cm thick are present at 407.8 m and 408.6. Sideritic cementation of the silty mudstone is present at 415.6, this is in gradational contact with

Viking Formation

415.7-419.1	Silty sandstone. This is medium dark grey (N4) in colour, very fine-grained and quartzose. It contains discontinuous lenses of very fine grained sandstone some of which are cross laminated. Thin, horizontally laminated, mudstone lenses also occur. The interval has been extensively bioturbated. Many flattened sand filled burrows occur. <u>Teichichnus</u> is present.
419.1-419.5	Sandstone. Olive grey (5Y 4/1), fine- to medium-grained, quartzose with extensive sideritic cementation. It is highly bioturbated and contains sand filled burrows, it grades into sandy siltstone similar to that of the interval 415.7-419.1 m. Contains glauconite. It is in sharp contact with
420.3-421.2	Mudstone. Similar to that of interval 407.2 - 415.7 m Contains a black, rounded phosphate nodule 2 cm in length. A thin light grey (N7) bentonite occurs at 420.3 m.
421.2-423	Muddy sandstone. Similar to that of interval 415.7-419.1 m but with a greater mud content and much less extensive bioturbation. Glauconite is present. There is a 10 cm thick siderite concretionary layer at the top of the interval.

Joli Fou Formation

423-429.1*	Mudstone. As in interval 407.2-415.7 m.

* 25% Recovery.

APPENDIX II

Description of thin sections taken from the Lower Colorado Succession of Southeastern Saskatchewan.

VIKING FORMATION

Socony Central Del Rio West Ratcliffe 22-13
LSD 13-22-1-16 W2

Depth of sample - 1189 metres below K.B.

Very fine-grained subgreywacke.

Texture
Grains are in point or long contact, many are floating in the matrix. There is a bimodal distribution of quartz grains. The average diameter of the larger grains is approximately .1 mm the smaller grains have a diameter of less than .05 mm. The grains display a well developed parallel alignment. The section displays well developed grading of coarse sand into fine-grained siltstone layers. This grading is repeated with a coarse layer seen in sharp contact above a fine-grained layer.

Mineral Composition
Terrigenous ; Quartz grains form approximately 60% of the section. Grains show original outlines. Sutured contacts are absent. A few grains of highly chloritised plagioclase feldspar are seen. Small laths of muscovite are present. Biotite showing alteration to chlorite is also present. A few scattered crystals of zircon are seen.
Organic ; Black/brown organic material forms approximately 15% of the section. It occurs mainly as irregular shapeless masses within the matrix or as large discontinuous horizontal lamellae. These laminae have a better development within the finer grained layers.
Matrix ; This is highly siliceous consisting mainly of microcrystalline silica. It contains abundant chlorite and sericite.

Diagenetic History
The quartz grains were cemented by a matrix consisting of a soft silica gel containing accessory clays. Secondary alteration of feldspars and clay minerals occurred.

VIKING FORMATION

Socony Central Del Rio West Ratcliffe 22-13
LSD 13-22-1-16 W2

Depth of Sample -1191 metres below K.B.

Very fine-grained quartzose sandstone.

Texture

Grains are in long or sutured contact. There is a bimodal distribution of grain sizes. The larger grains have an average diameter of .1 mm, the average diameter of the smaller grains is .05 mm. Grain shapes are subangular to subrounded. There is a well developed horizontal alignment. The sandstone is quite mature.

Mineral Composition

Terrigenous ; Quartz makes up approximately 90% of the section. Authigenic quartz is seen at the junctions of some grains. Sutured contacts are seen but in most cases the original grain shapes are retained. Plagioclase feldspar is present though forming less than 1% of the section. Many grains are highly sericitised. Muscovite is present, many grains have been highly deformed by grain to grain diagenetic pressures. A few crystals of zircon are present.

Matrix ; A small amount of microcrystalline chert is present occuring both as a cement and as rounded patches. In places these patches are seen to have corrosive contacts with surrounding organic material. Alteration products in the form of sericite and chlorite are widely dispersed throughout the section.

Organic Material ; This forms about 10% of the section occurring as small irregular masses, often obscuring contact relationships between grains.

Diagenesis

A chert forming silica gel acted as a limited primary cementing agent. Authigenic quartz formation at grain edges created sutured contacts between grains. Secondary alteration of feldspars and micas caused sericite and chlorite formation.

VIKING FORMATION

Socony Central Del Rio West Ratcliffe 22-13
LSD 13-22-1-16 W2

Depth of Sample - 1196 metres below KB.

Very fine-grained quartzose subgreywacke.

Texture

Quartz grains are generally in point or long contact, a few are floating in the matrix. The average quartz grain size is .1mm in diameter. These are set in a matrix in which grain size is less than .05 mm. The grains are subangular to subrounded. There is a well developed horizontal alignment of grains. Irregular horizontal organic lamellae are present.

Mineral Composition

Terrigenous ; Quartz grains form about 50% of the section. Most have sharply defined grain boundaries, a few show interfingering with the matrix. Many small grains of muscovite are present.

Organic ; Black/brown organic carbonaceous material is present as large irregular masses up to 1 mm in diameter. This forms smaller masses within the matrix and occurs as discontinuous rather disrupted horizontal layers.

Matrix ; This forms approximately 40% of the section. This is largely silicic in character being made up of microcrystalline quartz intermixed with clay minerals such as sericite and chlorite. Other indeterminate clay minerals are present.

Diagenesis

The unconsolidated material was subject to bioturbation. Slight authigenic growth of quartz took place prior to compaction and consolidation. Secondary alteration of clays occurred within the matrix.

VIKING FORMATION

Oungre 1
LSD 7-1-2-14 W2

Depth of sample 1156.7 metres below K.B.

Very fine-grained quartzose sandstone.

Texture

Grains are in sutured or long contact. There is no visible porosity. There is a bimodal grain size distribution, the larger grains have an average diameter of .2 mm, the average diameter of the smaller grains is .07 mm. Grain shapes are angular to subangular. There is a well developed horizontal alignement of quartz grains and organic material. The sandstone is quite mature.

Mineral Composition

Terrigenous ; Quartz forms 80% of the section. Many of the grains show evidence of authigenic quartz growth. This has led to the development of idiomorphic outlines and sutured contacts to give a quartzose texture. A few small grains of plagioclase and microcline feldspar are present. Muscovite is present, in places it is highly deformed owing to diagenetic pressures.

Organic ; Black/brown carbonaceous material forms approximately 20% of the section either as irregular masses up to 2.5 mm in diameter or as disjoint horizontal laminae. In some places organic material is corroded by authigenic growth. Pockets of organic material are seen in pdaces surrounding the original outlines of quartz grains, these in turn have been surrounded by authigenic quartz growth.

Diagenesis

Cementation is by primary quartz solution giving rise to authigenic quartz formation and development of a restricted quartzose texture.

VIKING FORMATION

Shell Midale A-7-18
LSD 7-118-6-10 W2

Depth of sample - 894.6 metres below K.B.

Medium- to fine-grained calcareous sandstone.

Texture

Grains are mainly in point, length or sutured contact, with some floating in the matrix. There is no visible porosity. There is a bimodal grain size distribution. Larger grains have a maximum diameter of 1.5 mm and an average grain size diameter of .7 mm. The smaller grains have an average grain size of .3 mm. Generally the larger grains are rounded to subrounded in shape while the smaller ones are angular to subangular. There is a weak horizontal alignment of larger grains.

Mineral Composition

Terrigenous ; Quartz makes up about 80% of the section. Some grains show a highly strained extinction. Authigenic growth is common in many grrains, some show idiomorphic outlines and sutured contacts. A few scattered flakes of muscovite are present. One well shaped zircon crystal is seen. Two small rounded fragments of iron rich fine-grained quartz sandstone are present.

Cementation ; Calcite makes up about 15% of the section, forming a uniform crystalline cement. It is seen outlining the original quartz grains prior to authigenic quartz deposition. A limonite cement occurs in broad bands throughout the section forming about 5% of the rock. In places it is corroded and penetrated by growth of quartz.

Diagenesis

Calcite, quartz and iron rich solutions were primary and penecontemporaneous cementing agents within this rock. Pressure solution was not a factor in the cementation.

BIG RIVER FORMATION

Socony Central Del Rio Grassdale 1
LSD 6-2-7-16 W2

Depth of sample - 890 metres below K.B.

Fine grained quartzitic sandstone with siderite/calcite cementation.

Texture

Grains are in long or sutured contact. There is unimodal grain size distribution with grains having an average diameter of .2 mm. Shapes are subangular to subrounded with no alignement of grains. Due to the fragmentary nature of the section porosity cannot be determined. The sandstone is quite mature.

Mineral Composition

Terrigenous ; Quartz forms approximately 60% of the section. Many grains display highly strained extinction. Some of the quartz grains show idiomorphic outlines due to authigenic quartz growth. Quartzose texture occurs in places due to this new growth of quartz. The original outlines of the quartz grains do not appear to be in contact. A few small grains of plagioclase feldspar of indeterminate composition are present. A few crystals of muscovite with highly strained lamellae are present. Fragments of highly strained quartz containing aligned crystals of muscovite are present also.

Cementation ; Chert forms approximately 20% of the section. It occurs as rounded, shapeless pockets of microcrystalline chalcedonic silica. It also occurs as a cement between quartz grains. In places it is corroded by authgenic quartz growth. Sparitic calcite is present as a cement in some areas. Small vein segregations of calcite also occur. It is seen to surround and corrode authigenic quartz growths. It occurs in small pockets outlining original quartz grain shapes. This was then surrounded by the secondary quartz growth.

A band 2 mm wide running through the section is made up of coarsely crystalline, often rhombahedral, crystals of siderite. This band incorporates many grains of quartz and chert. It is penetrated in many places by authigenic quartz growth. In places crystals of siderite are partially surrounded by chert segregations. Siderite is also seen acting as a cement surrounding qquartz grains and chert segregations. Scattered crystals of siderite also occur in isolation throughout the section. Limonite is formed in places through the alteration of siderite.

Organic ; A phosphatic cone, approximately .8 mm in length is present.

Diagenesis

Quartz, calcite, chalcedonic silica and siderite are primary or contemporaneous cements. Calcite and siderite are penecontemporaneous cements. Limonite is secondary. The origin of the quartz cement was not due to pressure solution as the original quartz outlines are not in contact. Therefore cementation came into operation before compaction.

BIG RIVER FORMATION

Imperial Federated Coop Palmer
LSD 12-29-1-5 W2

Depth of sample - 1031 metrres below K.B.

Very fine-grained quartzose sandstone.

Texture

Grains are in long or sutured contact. Porosity is approximately 15%. Grain sizes show a unimodal distribution with the average diameter of the quartz grains being approximately .1 mm. Grains are subangular to subrounded and show a well developed parallel alignment. The sandstone is mature. Organic structure in the form of sand filled burrows are common. These are oval structures ranging from 2.25 to 1.0 mm in diameter. The burrows are outlined by organic material and are filled with non-aligned quartz grains and organic material.

Mineral Composition

Terrigenous ; Quartz forms 90% of the section. Many grains show highly strained extinction. Edges of grains show sutured or straight contacts forming a quartzose texture. Some interstitial spaces between grains show infilling by authigenic quartz growth. A few small angular grains of microcline and plagioclase feldspar are present. Many crystals of zircon and a few blades of muscovite are scattered throughout the section.

Organic ; Abundant black/brown carbonaceous organic matter, possibly containing limonite, form widespread irregular horizontal laminae within the section. This material also occurs between individual quartz grains, either obscuring the contacts or acting as a cement.

Diagenesis

The loose sediment consisting of sand and organic material was subjected to extensive bioturbation. Cementation was by chemical precipitation giving rise to authigenic quartz growth.

APPENDIX IIa

List of thin sections examined from the Lower Colorado Succession Southeastern Saskatchewan, from outside selected study area.

VIKING FORMATION	Depth of sample below K.B. (metres)
Imperial Esk 7-14-33-20 LSD 7-14-33-20 W2	419.4
Imperial Kuroki 7-30-34-10 LSD 7-30-34-10 W2	362.1
Canadian Gulf Margo 2 LSD 12-1-32-8 W2	342.6
Imperial Okla 1-29-35-8 LSD 1-29-35-8 W2	393.2
Sohio WP Sheho 1 LSD 4-10-30-8 W2	339.5
Sohio Western Petroleum Tiny 1 LSD 1-14-31-5 W2	267.9
JOLI FOU FORMATION	
Sohio Allenbee Whitesand 13-7-32-8 LSD 13-7-32-8 W2	409.9

APPENDIX III

Elevations of Principal Correlation Surfaces of the Lower Colorado Succession in Southeastern Saskatchewan.

Well Name	Location	K.B. (m)	Tops: Mannville	Joli Fou	Viking	Big River
Plaza-Amnat-Security Antler 3-9-1-30	03-09-01-30 W1	487	756	-	-	843
Sun Gainsborough 13-15	13-15-02-30 W1	493	710	-	-	596
Acroll et al Cayuga 12-21-3-30	12-21-03-30 W1	506	705	-	-	594
Strain Atkinson Woods Ingoldsby 16-16-4-30	16-16-04-30 W1	514	685	-	-	575
Woods Petroleum Fertile Valley 16-7	16-07-05-30 W1	523	683	-	-	572
Pinn-JI-Mobil Kelvindale 10-16-6-30	10-16-06-30 W1	544	674	-	-	557
Central-Del Rio Sinclair Antler 12-30	12-30-07-30 W1	571	672	-	-	556
Mobil Oil-Woodley-Sinclair North Antler X-8-18	08-18-08-30 W1	573	652	-	-	541
Fortenbery East Ryerson 8-23-9-30	08-23-09-30 W1	565	611	-	-	500
Benson Montin Greer Maryfield Crown 8-14	08-14-10-30 W1	557	585	-	-	477
CPOG Tenn Kirkella 12-25-11-30	12-25-11-30 W1	555	556	520	509	452
Texaco Fleming R/A 13-32-12-30	13-32-12-30 W1	555	567	524	523	456
Tenneco Fleming 4-11-13-30	04-11-13-30 W1	540	513	472	470	405

Well Name	Location	K.B. (m)	Tops			
			Mannville	Joli Fou	Viking	Big River
California Standard Tidewater Boundary 5-14	05-14-14-30 W1	518	467	426	424	360
Rio Palmer California Standard Welwyn 16-17	16-17-15-30 W1	522	453	413	411	347
Rocan Rocanville 5-7-16-30	05-07-16-30 W1	518	444	399	398	333
Noranda Tombill Maarthe 1-16-17-30	01-16-17-30 W1	481	375	-	-	327
Trans Empire Imperial Welby 14-16	14-16-18-30 W1	487	363	316	314	260
Canberra Spy Hill 9-14	09-14-19-30 W1	492	343	303	300	245
Riddle Tidewater Marchwell Crown 1-16-20-30	01-16-20-30 W1	302	362	313	311	253
KPL-Champ-Sun Workman 13-16-1-31	13-16-01-31 W1	500	788	-	-	667
Imperial Carievale 5-16-2-31	05-16-02-31 W1	506	765	-	-	645
KPL Tream Fina Carievale 6-17-3-31	06-17-03-31 W1	517	757	-	-	642
Mobil Oil Woodley Sinclair 16-12	12-16-04-31 W1	530	737	-	-	625
Smus Nottingham 6-16-5-31	06-16-05-31 W1	546	732	-	-	618

Well Name	Location	K.B. (m)	Tops			
			Mannville	Joli Fou	Viking	Big River
Kissinger Alminex Liberty Bellegarde 8-20-6-31	08-20-06-31 W1	570	721	-	-	609
Rio Palmer Admiral et al Redvers 1	01-17-07-31 W1	590	727	-	-	611
MM-RC Mair 13-31-8-31	13-31-08-31 W1	604	700	-	-	587
Mobil Oil-Pure-Sinclair Ryerson X-4-22	04-22-09-31 W1	585	658	-	-	543
Tidewater Ryerson Crown 1	04-10-10-31 W1	587	643	-	-	533
Benson-Montin Greer-Rotave-Cr. 16-22	16-22-13-31 W1	576	558	-	-	450
Riddle-Tidewater (N) Moosomin Crown 5-24	05-24-14-31 W1	539	492	-	-	386
Rocan Rocanville 13-21-15-31	13-21-15-31 W1	542	483	-	-	373
Canus PLC BP Rocan 2-16-16-31	02-16-16-31 W1	526	454	-	-	345
Security-White Rose Tantallon 3-32-17-31	03-32-17-31 W1	518	424	-	-	312
Trans Empire Tide Water WElby 9-20	09-20-18-31 W1	492	383	-	-	273
Internatienal Spy Hill 16-4-19-31	16-04-19-31 W1	501	399	338	335	277
IMC Gerald 16-9-20-31	16-09-20-31 W1	511	400	-	-	271

Well Name	Location	K.B. (m)	Tops Mannville	Joli Fou	Viking	Big River
Champlin Phillips Elmore 15-15-1-32	15-15-01-32 W1	505	817	-	-	695
Kissinger-Canso Climax Co-op Carnduff 13-15	13-15-02-32 W1	514	816	-	-	692
Devon-Palmer-Bishop-Francana Silverton 2-15	02-15-03-32 W1	519	778	-	-	661
L-M Calstan Ingoldsby 4-15	04-15-04-32 W1	534	769	-	-	649
Kissinger Nottingham 1-15-5-32	01-15-05-32 W1	555	749	-	-	640
Strain Atkinson & Wood Lightning Creek 4-15	04-15-06-32 W1	581	757	-	-	642
Imperial Redvers 4-23-7-32	04-23-07-32 W1	599	738	-	-	626
Champdin Annandale 2-16-8-32	02-16-08-32 W1	616	731	-	-	622
Tidewater Mair Crown 1	01-11-09-32 W1	607	705	-	-	591
Benson-Montin Greer-Walpole Crown 16-28	16-28-10-32 W1	599	661	-	-	551
Texaco Doonside 13-23-11-32	13-23-11-32 W1	598	637	592	589	523

Well Name	Location	K.B. (m)	Tops Mannville	 Joli Fou	 Viking	 Big River
Central Del Rio Red Jacket 6-19	06-19-13-32 W1	601	593	548	543	482
Quasar Mana Red Jacket 4-14-14-32	04-14-14-32 W1	581	568	520	518	454
Tidewater Central Del Rio Rocanville Crown 9-22	09-22-15-32 W1	567	524	-	-	412
Canus PIC BP Rocan 2-22-16-32	02-22-16-32-W1	557	517	439	439	374
Ashland Tb Rocanville N10-16-17-32	10-16-17-32 W1	530	443	-	-	338
Consolidated Merrison Tantallon 9-26	09-26-18-32 W1	506	393	348	346	285
IMC Gerald 16-10-19-32	16-10-19-32 W1	510	396	350	346	287
International Yarbo 2	13-16-20-32 W1	510	269	-	-	379
IOE Pleasant Plains 9-23-1-33	09-23-01-33 W1	527	873	-	-	748
Canadian Superiop Baglole 13-15	13-15-02-33 W1	528	856	-	-	728
Chandler Arco Hastings 16-15-3-33	14-15-03-33 W1	541	824	-	-	702
Gulf Hastings Hamilton 4-15-4-33	04-15-04-33 W1	548	006	-	-	685
Scurry Nottingham 16-15	16-15-05-33 W1	576	791	-	-	674
Mutual IOE Edenvale 10-16-6-33	10-16-06-33 W1	594	793	-	-	674
SMPS Wauchope 6-11-7-33	06-11-07-33 W1	612	770	-	-	655

Well Name	Location	K.B. (m)	Tops			
			Mannville	Joli Fou	Viking	Big River
Summit et al S. Parkman 4-15-8-33	04-15-08-33 W1	636	722	-	-	659
Imperial Parkman 12-15	12-15-09-33 W1	645	748	707	703	636
Tidewater Canadian Superior Fairlight Cr. 1	04-13-10-33 W1	420	697	655	652	585
Canadian Export Gas Canadian Prospect Wawota 13-27	13-27-11-33 W1	626	687	-	-	570
Tenn. A. 1 Wawota 10-3-12-33	10-03-12-33 W1	618	669	-	-	523
Benson-Montin Greer Riga 10-14	10-14-13-33 W1	583	596	-	-	489
KPL-Clark Canadian-Wapella 13-22-14-33	13-22-14-33 W1	589	579	-	-	467
Devon Palmer Wapella 11-16	11-16-15-33 W1	596	571	-	-	456
Triton Tidewater Carnoustie Crown 9-12	09-12-17-33 W1	564	489	-	-	378
International Yarbo 23 5-22-20-33	05-22-20-33 W1	523	394	-	-	286
KPL Prarie Souris Flats 11-23-1-34	11-23-01-34 W1	552	944	-	-	813
Imperial Florence 13-15 M	13-15-02-34 W1	547	898	-	-	768

Well Name	Location	K.B. (m)	Tops			
			Mannville	Joli Fou	Viking	Big River
Kissinger Clarke 10-15	10-15-03-34 W1	555	870	-	-	741
Williamson Olean 6-15	06-15-04-34 W1	559	837	-	-	714
Kissinger-SRMI-Cantal 112-15-5-34	10-15-05-34 W1	574	820	-	-	696
Kiissinger Sr Mi Queensdale 12-15-6-34	12-15-06-34 W1	594	811	-	-	677
Williamson Crown Wauchope 8-24	08-24-07-34 W1	631	813	-	-	695
KCI Service 2-35-8-34	02-35-08-34 W1	663	790	753	738	674
Worldwide Parkman 2-24-9-34	02-24-09-34 W1	647	764	725	706	642
Joe Philips Parkdan 12-2-10-34	14-02-10-34 W1	664	766	-	-	651
Tidewater Imperial Wawota Crown 1	00-12-11-34 W1	660	744	704	684	618
Mich. Wis. Clark W. Kimberly 15-16-1-1	15-16-01-01 W2	572	1000	-	-	870
Dome Provo Scurry Glen Ewen 9-17-2-1	09-17-02-01 W2	564	947	-	-	813
Whitehall Westburne Glen Ewen 3-16	03-16-03-01 W2	563	891	-	-	768
Rio Palmer West Cadadian Oxbow 1	16-15-04-01 W2	564	846	-	-	785
Imperial Auburton 12-21-5-1	12-01-05-01 W2	580	840	-	-	713

Well Name	Location	K.B. (m)	Tops: Mannville	Joli Fou	Viking	Big River
Stekoll Phillippe 16-21	16-21-06-01 W2	593	804	-	-	688
Imperial Maanor 2-23	02-23-07-01 W2	625	820	-	-	699
Gridoil West Manor 2-27	02-27-08-01 W2	646	803	762	752	684
Francana Can Will Papkman 14-22-9-1	14-22-09-01 W2	683	799	-	-	683
Canpet Tidewater et al Adelaide 4-22	04-22-10-01 W2	669	768	-	-	650
Francana Comaplex Dumas 13-19-11-1	13-19-11-01 W2	676	749	710	703	646
Sohio South Wapella 13-10	13-10-14-01 W2	608	622	-	-	504
KPR Clark Canadian Wapella 9-21-15-1	09-21-15-01 W2	594	591	-	-	475
Devon-Palmer East Whitetood 1-16-16-1	01-16-16-01 W2	596	562	-	-	456
Hudson Whitewood 5-16-17-1	05-16-17-01 W2	600	552	-	-	439
Cego et al Northgate 3-18-1-2	03-18-01-02 W2	565	1036	981	975	900
Imperial Marconi 9-23-2-2	09-23-02-02 W2	583	973	920	918	840
Imperial Oxbow 1-15M-3-2	01-15-03-02 W2	576	940	-	-	810
B.A. Beharrel	11-22-04-02 W2	580	884	-	-	756
Imperial Queensville 6-16	06-16-05-02 W2	589	873	-	-	744

Well Name	Location	K.B. (m)	Tops: Mannville	Joli Fou	Viking	Big River
WE Bakke Aztec Queensdale 8-16-6-2	08-16-06-02 W2	602	856	-	-	729
American Liberty 10-23	10-23-07-02 W2	613	820	773	767	695
Placid Tidewater Carlyle 6-22	06-22-08-02 W2	664	847	803	785	717
Pure White Bear Crown 8-9-9-2	08-09-09-02 W2	705	864	823	807	741
Moc et al Moose Mtn Cr. 4-22-10-2	04-22-10-02 W2	742	848	801	796	730
Imperial Tidewater Dumas 1-20-11-2	01-20-11-02 W2	690	784	-	-	661
Francana-Langbank 2-28-12-2	02-28-12-02 W2	672	735	-	-	615
Tidewater-Sohio West Wapella 16-33	16-33-14-02 W2	613	624	-	-	508
BA Silverwood Hoggarth 4-20-15-2	04-20-15-02 W2	610	615	-	-	495
Lake Echo Whitewood 11-15-16-2	11-15-16-02 W2	597	575	521	519	457
Hadson Whitewood 1-12-17-2	01-12-17-02 W2	593	557	509	507	445
BA Fertile Belt Serdula 4-34-18-2	04-34-18-02 W2	597	522	-	-	409
Hadson Esterhazy 3-29-19-2	03-29-19-02 W2	532	437	-	-	321
CPOG Northgate 3-21-1-3	03-21-01-03 W2	564	1082	-	-	937
CND Sup et al Openshaw 15-9-2-3	15-09-02-03 W2	573	1021	-	-	888

Well Name	Location	K.B. (m)	Tops Mannville	Joli Fou	Viking	Big River
Kissinger et al 1-23	01-23-03-03 W2	578	966	-	-	831
Plaza American Natural Alameda 7-15-4-3	07-15-04-03 W2	588	930	-	-	799
Imperial Douglaston 5-25-5-3	05-25-05-03 W2	594	865	-	-	740
Placid Dalesboro Willmar 4-22-6-3	04-22-06-03 W2	595	853	-	-	731
Plaza Wordsworth 4-22-7-3	04-22-07-03 W2	609	848	796	792	721
Whitehall Gerc Arcda N. 14-21-8-3	14-21-08-03 W2	640	848	803	784	718
Tidewater Ajax Whitebear 4	09-12-09-03 W2	738	916	866	857	789
Kenosee Unit Cr DD 10-22-10-3	10-22-10-03 W2	755	946	877	874	796
Marathon E. Fletwode Cr 10-20-11-3	10-20-11-03 W2	717	847	-	-	689
Tidewater Langbank Crown 1	16-14-13-03 W2	658	714	-	-	589
Sohio St. Hubert 9-36	09-36-14-03 W2	621	629	-	-	495
Sohio St. Hubert 14-1	14-01-15-03 W2	623	641	-	-	519
Huber Mana BA Broadview 2-14-16-3	02-14-16-03 W2	611	593	-	-	476
CPOG Noel Whitewood No 10-11-17-3	10-11-17-03 W2	591	564	-	-	448
CDR Broadview 11-12-18-3	11-12-18-03 W2	450	392	341	339	275

Name	Location	K.B. (m)	Tops: Mannville	Joli Fou	Viking	Big River
3angor 8-29-20-3	08-29-20-03 W2	528	-	381	378	314
a Portal 4-15	04-15-01-04 W2	575	1096	1031	1030	957
an Pinto 12-15-2-4	12-15-02-04 W2	571	1035	981	966	893
Steelman 5-18-3-4	05-18-03-04 W2	579	1011	957	941	866
: Monterey Rockland 7-21	07-21-04-04 W2	590	961	907	896	821
id et al Steelman 1-16-5-4	01-16-05-04 W2	455	926	872	860	782
.er Willmar 11-16-6-4	11-16-06-04 W2	596	892	836	834	764
Vaughan 9-21	09-21-07-04 W2	610	862	813	799	728
ter Imperial Arcola Crown 1	01-22-08-04 W2	623	838	793	775	706
ico Kiippen LK No. 13-17-9-4	13-17-09-04 W2	768	954	903	892	824
ter Kenosee Crown 2	16-23-10-04 W2	753	888	826	823	758
I.O.L. Fletwode 14-21	14-21-11-04 W2	737	860	-	-	724
-Jordan 1 Golden Spring 2-4	10-05-12-04 W2	723	833	-	-	700
Tidewater Beynes 14-22	14-22-15-04 W2	615	639	-	-	516

Well Name	Location	K.B. (m)	Tops Mannville	Joli Fou	Viking	Big River
B.A. Elcapo Hausch 13-11-16-4	13-11-16-04 W2	625	616	-	-	496
H.B. Ochapowace 2-36-17-4	02-36-17-04 W2	595	560	-	-	444
CPOG Kahkewistahaw 5-18-18-4	05-18-18-04 W2	594	548	489	488	432
Tidewater Imperial Cotham Crown 1	01-02-19-04 W2	562	491	441	439	379
Scurry ML Pinto 14-23-1-5	14-23-01-05 W2	564	1099	1037	1032	954
Supst Loc Pinto W. 15-23-2-5	15-23-02-05 W2	574	1048	987	984	914
Rio Palmer Martin 15-21	15-21-03-05 W2	587	1032	971	957	883
J. Lischka B-13-15	13-15-04-05 W2	589	983	930	915	841
Devon Palmer-Bishop-Francana Breeze 15-23	15-23-05-05 W2	596	941	889	875	802
IOE Browning 15-22M-6-5	15-22-06-05 W2	605	907	852	839	767
KPL-ALMX-LBTY Clarilaw	13-15-07-05 W2	611	875	818	812	743
Champlin et al Kisbey 5-21-8-5	05-21-08-05 W2	624	859	799	796	725
CPOG Hassard Lake 9-15-9-5	09-15-09-05 W2	769	927	909	906	-
Tidewater Kenosee Crown 3	05-15-10-05 W2	773	946	886	881	810

Well Name	Location	K.B. (m)	Tops Mannville	Joli Fou	Viking	Big River
Imperial Hazelwood 2-22	02-22-11-05 W2	755	883	818	815	744
Garvey-Jordan Bendee No. 6-12-12-5	06-12-12-05 W2	749	851	791	789	719
Tidewater Kipling Cr 1	14-22-13-05 W2	660	731	-	-	597
Tidewater Hillesden Crown 1	05-30-15-05 W2	656	695	-	-	559
Placid Tidewater Ekapo 5-14	05-14-16-05 W2	603	603	-	-	482
Sohio Grenfell 16-20	16-20-17-05 W2	589	561	-	-	442
CPOG Crooked Lake 2-30-18-5	02-30-18-05 W2	570	537	-	-	407
Grayson 1	04-29-20-05 W2	546	459	407	406	343
Candel Percee 8-27-1-6	08-27-01-06 W2	573	1124	1070	1054	977
Kissinger Taylorton 11-23-2-6	01-23-02-06 W2	576	1084	1023	1014	935
Husky Mic Mac Can. Cup. Kingsford 1	07-26-03-06 W2	584	1025	972	950	878
Steelman Unit Two B7-15-4-6	07-15-04-06 W2	592	999	935	932	858
K-S Chctv N. Steelman 15-22-5-6	15-22-05-06 W2	599	954	896	886	815
Tidewater Imperial Lapman Crown 1	05-28-06-06 W2	604	921	858	853	783
Tidewater Imperial S. Kisbey Crown 2	12-22-07-06 W2	615	884	-	-	752

Well Name	Location	K.B. (m)	Tops Mannville	Joli Fou	Viking	Big River
North Kisbey 11-22	11-22-08-06 W2	608	844	-	-	711
Imperial Star Valley 1-23-M9-6	01-23-09-06 W2	683	872	820	872	745
Imperial Warmley 6-23-10-6	06-23-10-06 W2	777	949	-	-	813
Canadian Export Gas Canadian Prospect Moose Mtn 16-24	16-24-11-06 W2	741	876	-	-	735
Canpet Cree Mining et al Moose Valley 2-23	02-23-12-06 W2	741	831	-	-	701
Triton Tide Water Marston Lake Cr 16-2	16-02-16-06 W2	639	666	589	587	531
Sohio Grenfell 9-24	09-24-17-06 W2	585	557	508	506	438
Sharples California Standard Sakimay 1-8	01-08-18-06 W2	580	564	515	514	439
Imperial Cowessess 2-2-19A-6	02-02-19A-06 W2	568	517	471	469	402
H.B. Killaly 11-29-20-6	11-29-20-06 W2	555	472	420	418	357
Dome Provo Roche Percee 5-23	05-23-01-07 W2	574	1129	1074	1071	994
Kissinger Estevan B 15-35	15-35-02-07 W2	583	1066	1012	1001	924

Well Name	Location	K.B. (m)	Tops Mannville	Joli Fou	Viking	Big River
Kissinger Mobil Estevan A 13-18	13-18-03-07 W2	581	1065	1009	995	919
Shell Glushak 15-15	15-15-04-07 W2	597	1009	952	945	871
Texaco North Kingsford 1-11-5-7	01-11-05-07 W2	596	979	920	917	844
Coop-Scurry Menard 9-23-6-7	09-23-06-07 W2	604	934	873	872	798
Freeholders Forget 1-31-7-7	01-31-07-07 W2	609	904	839	836	766
Pinn Srml Forget 14-23-8-7	14-23-08-07 W2	613	866	806	804	731
Herkules CPOG Freestone 13-15-9-7	13-15-09-07 W2	613	839	774	769	703
Tenn A-2 Handsworth 7-15-10-7	07-15-10-07 W2	638	817	756	750	683
Ashland Kewanee Handsworth 3-6-11-7	03-06-11-07 W2	649	813	755	747	680
Tidewater B.A. South Windhorst Crown 14-28	14-28-12-07 W2	696	823	760	752	684
Triton-Tidewater Windhorst Crown 2-28	02-28-13-07 W2	676	770	713	703	633
Tidewater Grenfell Crown 1	07-10-16-07 W2	663	702	640	637	567
Sohio Grenfell 13-14	13-14-17-07 W2	589	586	533	527	457
B.A.H.P. Hyde 1	12-28-19-07 W2	587	542	497	473	411

Well Name	Location	K.B. (m)	Tops Mannville	Joli Fou	Viking	Big River
H.B. CDR Hyde 11-11-20-7	11-11-20-07 W2	563	488	442	429	370
White Rose Devon Palmer et al Boundary 16-4	16-04-01-08 W2	581	1174	1119	1111	11027
Imperial Estevan 2-21-2-8	02-21-02-08 W2	549	1081	1022	1013	933
Homestead Siboney Estevan 13-9	13-09-03-08 W2	581	1080	1027	1007	930
Kissinger Hitchcock Crown 3-16	03-16-04-08 W2	587	1021	963	557	880
CDR SR ML Bryant 1-21-5-8	01-21-05-08 W2	600	987	927	922	845
Gridoil et al Benson WW 15-23-6-8	15-23-06-08 W2	602	1179	883	881	607
Ambassador Imp. Viewfield 9-21-7-8	09-21-07-08 W2	615	932	866	864	790
KPL-Ames-FA & F-Fina Stoughton 5-15-8-8	05-15-08-08 W2	621	893	830	826	753
Vanderbilt Melrose 11-22-9-8	11-22-09-08 W2	615	844	783	775	705
Aloc Lost Horse Hill 1-15-10-8	01-15-10-08 W2	630	829	765	761	692
Wintershall IOE Handsworth 3-1-11-8	03-01-11-08 W2	643	813	750	746	677
H.B. Fillmore 4-26-12-8	04-26-12-08 W2	670	807	744	736	667

Well Name	Location	K.B. (m)	Tops: Mannville	Joli Fou	Viking	Big River
Imperial Illingworth 13-29	13-29-16-08 W2	665	710	655	634	564
Imperial Kegworth 3-14-14-8	03-14-14-08 W2	701	792	742	710	645
B.A. Husky Phillips Bemersyde 1	03-11-13-08 W2	675	794	744	715	647
B.A. husky Phillips Neudorf 6-20	06-20-20-08 W2	624	575	535	507	449
C.F.P. Tableland 1	10-29-01-09 W2	576	1149	1087	1083	983
White Rose Devon Palmer et al Tableland 8-22	08-22-02-09 W2	569	1088	1033	1029	946
Homestead Siboney Hitchcock 13-22	13-22-03-09 W2	583	1062	1032	994	917
CDR IOE Macoun 15-15-4-9	15-15-04-09 W2	586	1024	974	955	879
Magnolia Shell Bryant 1-24	01-24-05-09 W2	599	988	928	921	845
W.H. Hudson Viewfield 13-15	13-15-06-09 W2	602	955	-	-	816
Shell Huntoon A13-22	13-22-07-09 W2	613	936	-	-	793
Shell Estevan 1	06-24-08-09 W2	617	895	833	828	752
Francana et al Heward 3-11-9-9	03-11-09-09 W2	621	881	817	809	740
Homestead et al Creelman 3-23-10-9	03-23-10-09 W2	635	839	776	770	705

Well Name	Location	K.B. (m)	Tops: Mannville	Joli Fou	Viking	Big River
k.P.L. et al Gooseberry Lake	04-23-11-09 W2	630	809	761	728	663
Pure-Texas Pacific Gooseberry Lake 6-29	06-29-12-09 W2	640	799	746	725	660
B.A. Husky Phillips Glenavon 1	08-29-13-09 W2	670	785	726	710	649
B.A. Husky Phillips Kegworth 14-11	14-11-14-09 W2	692	781	727	710	649
F.P.C. Shell South Tableland 1-14	01-14-01-10 W2	585	1167	1110	1105	1025
White Rose Devon Palmer et al Outram 3-12	03-12-02-10 W2	581	1135	1074	1065	981
Campagnie Francaise Des Petroles Outram 1	01-19-03-10 W2	566	1068	1008	1003	920
Monsanto Sr Macoun 13-21-4-10	13-21-04-10 W2	583	1037	977	966	889
Shell Blewett A-1-22	01-22-05-10 W2	591	992	932	927	848
Ambassador East Midale 7-22-6-10	07-22-06-10 W2	605	952	889	886	811
Summit et al E. Innes 15-25-7-10	15-25-07-10 W2	610	923	859	853	781
Forest Froude 5-15-8-10	05-15-08-10 W2	615	908	844	836	766

Well Name	Location	K.B. (m)	Mannville	Joli Fou	Viking	Big River
			Tops			
Landa Innes 1-15	01-15-08-11 W2	608	898	852	813	744
Sohio Canamericam Creelman 5-21	05-21-09-11 W2	616	870	815	799	725
IOE Prarie 15-20-10-11	15-20-10-11 W2	611	844	789	768	695
Plaza Redwater Fillmore 4-14-11-11	04-14-11-11 W2	629	845	790	770	698
Dome et al Montmartre No 8-24-13-11	08-24-13-11 W2	658	792	739	717	653
Texaco Montmartre 13-1-14-11	13-01-14-11 W2	659	785	734	713	645
B.A. Husky Phillips Montmartre 1	12-11-15-11 W2	693	787	738	721	653
Pheas Jeff Lake Assin IR 15-27-16-11	15-27-16-11 W2	695	756	703	684	616
Shell Marienthal H-1-13	01-13-01-12 W2	601	1215	1152	1145	1051
Sprig Hudson's Bay Torquay 3-15-2-12	03-15-02-12 W2	597	1147	1102	1068	984
Banff et al Bromhead 15-19-3-12	15-19-03-12 W2	598	1082	1026	1006	923
Shell Elswick A-12-25	12-25-04-12 W2	559	1001	945	928	846
L-M Canadian Superior Anderson 13-21	13-21-05-12 W2	577	974	927	897	819
Cloc Can Will WEyburn 1-15-6-12	01-15-06-12 W2	585	966	914	888	811
Texcam Weyburn 4-16-7-12	04-16-07-12 W2	592	921	875	857	778

Well Name	Location	K.B. (m)	Tops: Mannville	Joli Fou	Viking	Big River
Clark et al Creelman 7-23-9-10	07-23-09-10 W2	611	861	813	786	713
I.O.E. Creelman 1-15-10-10	01-15-10-10 W2	626	849	798	777	708
California Standard Filmore Province 16-16	16-16-11-10 W2	656	850	797	772	704
Tenn B.A. A-1 Montmartre 6-29-13-10	06-29-13-10 W2	656	790	736	716	649
Pan American B-I Fillmore Crown 13-4	13-04-14-10 W2	660	781	731	709	642
Pheus Banff Wolsely 14-28-17-10	14-28-17-10 W2	602	635	581	563	496
B.A. Husky Phillips Ellisboro 1	08-36-18-10 W2	568	586	531	506	437
CDR Pheasant Creek R/A 4-11-20-110	04-11-20-10 W2	615	569	544	524	460
FPC Shell NOrth Long Creek 5-15	05-15-01-11 W2	592	1182	1127	1111	1028
CFP Torquay 2	12-20-02-11 W2	590	1130	1082	1050	968
Banff et al Torquay North 7-29-3-11	07-29-03-11 W2	583	1051	1004	999	915
FPC Shell Torquay 9-7	09-07-04-11 W2	566	1031	969	961	879
IHC Midale 13-23-5-11	13-23-05-11 W2	592	1003	940	923	846
Stokes 13-15	13-15-06-11 W2	598	965	916	882	808
Shell Innes A 4-22	04-22-07-11 W2	611	937	894	853	781

Well Name	Location	K.B. (m)	Tops Mannville	Joli Fou	Viking	Big River
Shell Hume E-9-28	09-28-08-12 W2	619	910	856	838	766
Hope Imp Brough 6-12-9-12	06-12-09-12 W2	611	897	843	820	745
BA HB Wheaton Magnus 1-9-10-12	01-09-10-12 W2	608	852	798	781	714
Sun Imp Osage 1-18-11-12	01-18-11-12 W2	607	826	774	750	680
Pan Am A-1 Fillmore Crown 5-20	05-20-13-12 W2	649	806	750	737	663
Barnwell Kendall 4-20-14-12	04-20-14-12 W2	663	790	732	719	650
Crawford E. Smith & Saskota Petroleum Co. Assiniboine 1	16-14-16-12 W2	685	781	714	694	633
Frontier Indian Head 14-3-19-12	14-03-19-12 W2	571	591	540	519	448
CDR Patrick R/A 4-34-20-12	04-34-20-12 W2	571	574	503	479	414
FPC Shell Boundary 7-13	07-13-01-13 W2	616	1253	1196	1176	1087
Shell FPC Bromhead F-15-24	15-24-02-13 W2	599	1140	1092	1053	968
Sun et al Bromhead 5-24-3-13	05-24-03-13 W2	560	1084	1031	1012	925
White Rose Canadian Superior Goodwater 5-15	05-15-04-13 W2	598	1044	995	962	879
Berk Marwood Weyburn 8-21-5-13	08-21-05-13 W2	578	978	925	896	816

Well Name	Location	K.B. (m)	Tops			
			Mannville	Joli Fou	Viking	Big River
Devon Palmer TEO Roughbark 16-6	16-06-06-13 W2	583	946	901	874	794
White Rose Canadian Superior Ralph 12-15	12-15-07-13 W2	570	908	859	841	762
Scurry East Weyburn 13-17-8-13	13-17-08-13 W2	587	893	842	824	744
Plymouth Sun Talmage 1	09-22-09-13 W2	613	883	828	812	753
Champlin Talmage 11-2-10-13	11-02-10-13 W2	605	863	812	796	717
Charter Sun Tyvan 7-15	07-15-12-13 W2	615	794	739	706	648
B.A. Husky Phillips Tyvan 1	09-11-13-13 W2	628	795	743	724	651
Palmer California Standard Marybone 3-16	03-16-14-13 W2	659	793	744	722	648
Phillips No. 1 Odessa	05-12-16-13 W2	675	761	708	687	621
Dillman Indian Head 6-32 A	06-32-19-13 W2	599	617	-	-	477
Sprig H.B. South Oungre 9-25-1-14	09-25-01-14 W2	672	1252	1195	1171	1082
Whitehall CDR CTO Oungre 9-15-2-14	09-15-02-14 W2	640	1180	1139	1103	1017
IOE CDR Scurry Tribune 2-8-3-14	02-08-03-14 W2	618	1140	1094	1084	976

Well Name	Location	K.B. (m)	Mannville	Joli Fou	Viking	Big River
			Tops			
IOE CDR Jewel 8-20-4-14	08-20-04-14 W2	611	1043	994	969	886
White Rose Canadian Superior Colgate 14-23	14-23-05-14 W2	596	981	930	906	824
Omega Weyburn 2-15-6-14	02-15-06-14 W2	589	939	890	866	786
Sohio Canadian Superior Weyburn 2-21	02-21-07-14 W2	583	909	858	840	756
Champlin Weyburn 11-24-8-14	11-24-08-14 W2	585	882	832	815	735
Sun Imp N. Weyburn 13-22-9-14	13-22-09-14 W2	592	857	809	788	711
Sun Imp Worcester 7-25-10-14	07-25-10-14 W2	603	838	786	770	692
Hope Imp Cedoux 4-12-11-14	04-12-11-14 W2	606	832	777	758	681
B.A. Husky Phillips Colfax 15-11	15-11-12-14 W2	610	794	746	730	656
B.A. Husky Phillips Francis 1	08-29-13-14 W2	606	761	707	684	611
B.A. Husky Phillips Vibank 1	05-29-15-14 W2	663	772	724	695	623
Socony Central Del Rio SE Ratcliffe 1	15-15-01-15 W2	695	1426	1199	1176	1083
CNEL CDR Oungre 9-24-2-15	09-24-02-15 W2	663	1205	1155	1133	1046
Supst Oungre 3-16-3-15	03-16-03-15 W2	708	1215	1162	1144	1054
IOE CDR Colgate 9-22-5-15	09-22-05-15 W2	612	1002	950	930	849

Well Name	Location	K.B. (m)	Tops: Mannville	Joli Fou	Viking	Big River
CDR S. Grassdale 9-15	09-15-06-15 W2	606	954	914	881	800
IOE CDR Meadowbrook 16-10-7-15	16-10-07-15 W2	772	939	886	869	772
Banner Laird Yeoman 1-18-8-15	01-18-08-15 W2	583	885	834	602	726✓
Richfield B-A Williston Sandercock 10-28	10-28-09-15 W2	575	825	784	764	682
Sun Imp McTaggart 4-2-10-15	04-02-10-15 W2	581	838	787	767	689
Richfield B.A. Home Colfax 7-10	07-10-11-15 W2	594	824	775	756	677
Agro Hurd 10-9	10-09-17-15 W2	680	756	710	692	608
Mobil Flat Laake 2-16-1-16	02-16-01-16 W2	682	1240	1190	1170	1079
Texaco Chevron Raatcliffe 16-12-2-16	16-12-02-16 W2	721	1260	1211	1189	1100
Pure Mobil Mather Lake 8-18	08-18-03-16 W2	716	1205	1157	1135	1047
Mobil Oil West Neptune 30-14	14-30-04-16 W2	684	1094	1052	1033	948
Mobil North Neptune X-13-24	13-24-06-16 W2	619	959	918	898	818
Imperial Hudson Bay Yeoman 13-22-8-16	13-22-08-16 W2	585	866	821	804	715
Hope Imp Yellow Grass 16-26-9-16	16-26-09-16 W2	579	842	791	769	687

Well Name	Location	K.B. (m)	Tops Mannville	Joli Fou	Viking	Big River
Richfield B.A. Williston Bechard 11-22	11-22-13-16 W2	583	741	699	673	594
B.A. Husky Phillips Davin 1	12-11-16-16 W2	653	750	706	691	600
Pheas Chevron Tenneco Regina East 6-29-18-16	06-29-18-16 W2	708	773	-	-	628
Tidewater Imperial Avonhurst Crown 1	01-29-19-16 W2	665	693	-	-	563
Scurry et al Lake Alma 1-23-1-17	01-23-01-17 W2	688	1210	1167	1150	1057
White Rose CFP Mobil Lake Alma 8-22	08-22-02-17 W2	714	1213	1164	1147	1053
Worldwide et al Neptune 9-25-3-17	09-25-03-17 W2	742	1215	1162	1145	1056
Tipco Murphy Skinner LK 13-18-4-17	13-18-04-17 W2	713	1126	1079	1059	975
White Rose-West Canadian-Mobil-Central Del Rio Radville 13-32	13-32-05-17 W2	643	1008	967	953	863
CDR Radville 5-21	05-21-06-17 W2	635	1074	1027	1010	924
B.A. Husky Phillips Trossachs 9-11	09-11-08-17 W2	603	891	843	817	732
Shell Yellowgrass A 13-22	13-22-09-17 W2	584	827	770	746	663
Richfield B.A. Home Bechard 12-11	12-11-13-17 W2	580	750	699	668	590

VITAE AUCTORIS

BORN : 17 th of December 1954, in Shropshire, England.

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